A STUDY OF THE BENTHIC ALGAE IN THE KELP BED OFF DEL MONTE BEACH, MONTEREY, CALIFORNIA

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A STUDY OF THE
BENTHIC ALGAE IN THE KELP BED OFF
DEL MONTE BEACH, MONTEREY, CALIFORNIA

by

John Luther Keithly

December 1974

Thesis Advisor: E. C. Haderlie

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A subtidal study of the benthic flora and substrate relief was conducted within the kelp bed off Del Monte Beach, near Monterey Harbor, Monterey, California. The study was carried out by utilizing SCUBA equipment, aerial photography, and ocean wave refraction/numerical computer programs.

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A preliminary analysis of the mapped data indicated that the frequency and density of five defined algal groups varied in relation to certain types of substrate. Aerial photographic interpretations revealed yearly variations in the kelp bed surface canopy. Theoretically derived refraction computations along a wave energy gradient were consistent with some observed changes in kelp bed species distribution.

A Study of the Benthic Algae in the Kelp Bed off Del Monte Beach Monterey, California

by

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Submitted in partial fulfillment of the
requirements for the degree of

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I am especially indebted to those persons who gave of themselves to invest time in situ with me — first and foremost being my wife who dove with me on fifty-two of the sixty-five diving days required for underwater research. Other divers who helped me were Bill Corse, Jack Mellor, Dr. Haderlie, Larry McGovern, Pat Cornelius, Don Healy, Kirk Evans, Dean Ihre, Ed O'Connell, Al Winter, and Kurt Mondloch. John Fanning was a constant source of boat support assistance.

I. INTRODUCTION

The subject of marine benthic ecology has been recently gaining increased attention. The Monterey Peninsula in particular, has acquired considerable prominence as an area worthy of detailed coastal biological research. This can be attributed to the abundance and diversity of the animal and plant communities to be found, a comparatively long history of locally active marine biologists, and to the Peninsula's economic interests both as an aesthetic tourist attraction, and for commercial reasons such as the small indigenous fishing fleet, the West Coast's only squid cannery, and local marine recreational business enterprises.

In an attempt to quantify the marine resources of the Monterey area, various ongoing research programs have evolved at institutions neighboring the bay. Local educational institutions such as Hopkins Marine Station, the Naval Postgraduate School, Monterey Peninsula College, Moss Landing Marine Laboratories and the University of California, Santa Cruz (Fig. 1), have provided a wealth of basic knowledge pertaining to many aspects of the overall oceanography of the area. Various agencies both in public and private sectors such as the State Water Quality Control Board, Associated Monterey Bay Area Governments (AMBAG), and Pacific Gas and Electric Company have invested heavily in efforts to understand the possible impact of pollutants which might contaminate the Bay waters. The California Department of

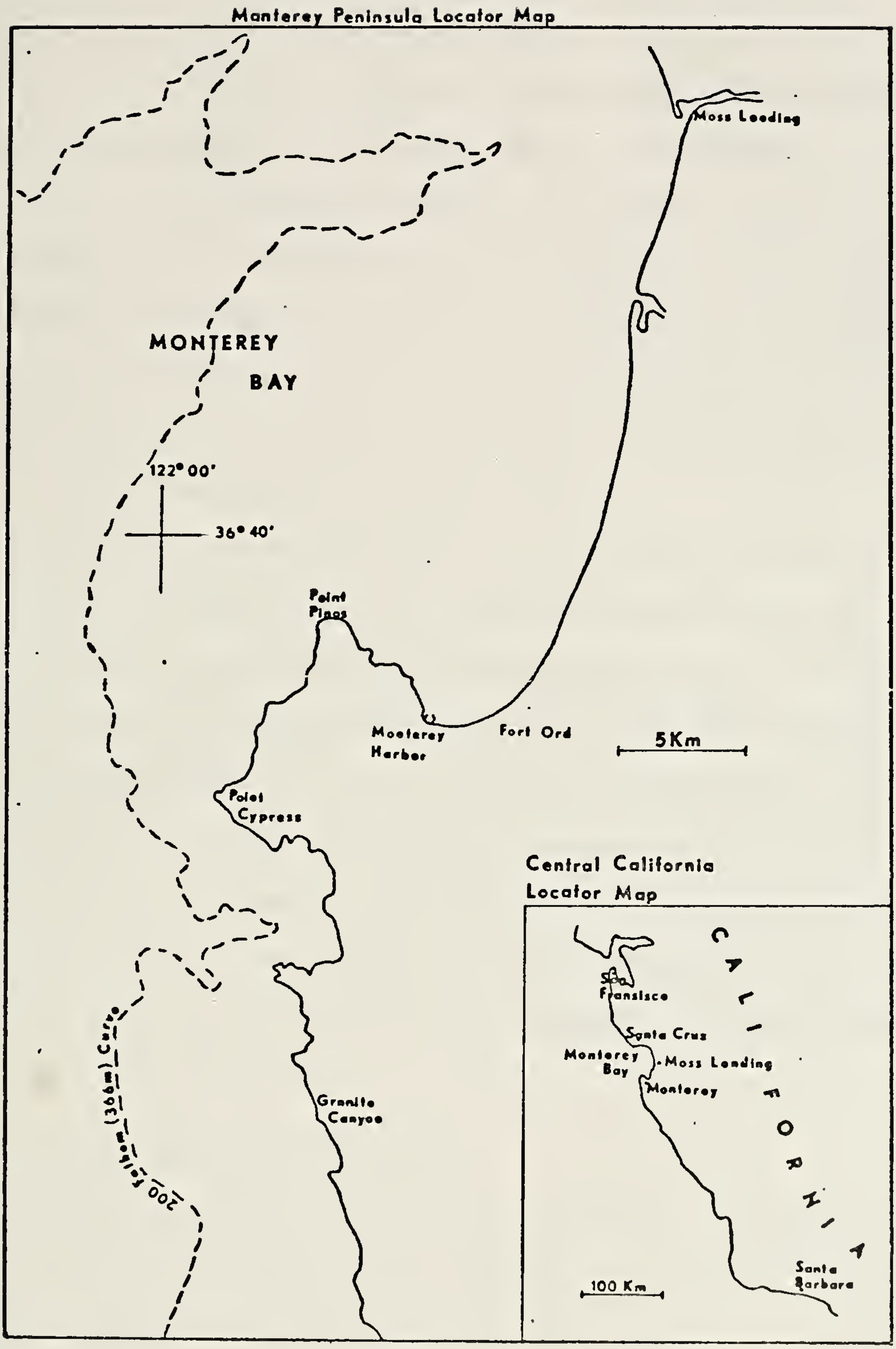

Monterey Peninsula Locator Map
Moss Landing
MONTEREY
BAY
122° 00'
36° 40'
Point Pinos
Monterey Harbor
Fort Ord
5Km
Point Cypress
Granite Canyon
200 fathom (366m) Curve
Central California Locator Map
CALIFORNIA
San Fransisco
Santa Cruz
Monterey Bay
Moss Landing
Monterey
Santa Barbara
100 Km

FIGURE 1

Fish and Game has devoted much attention to maintaining the best marine sporting fisheries for licensed fisherman and skindivers. It has also established a laboratory at Granite Canyon with hopes of obtaining fundamental information required for possible future aquaculture development.

The advent of multispectral photographic reconnaissance has added a new dimension to those engaged in environment monitoring. The U.S. Army Corps of Engineers for example, has been collecting aerial overflight photographs of the West Coast shoreline which would permit extensive regional analysis over extended periods of time.

Another relatively new tool in ecological research is the digital computer. Fleet Numerical Weather Central and the Environmental Prediction Research Facility, both located in Monterey, are immediately concerned with developing and verifying relevant numerical prediction models which might be of use to civilian and military organizations. Monterey Bay has been a convenient testing ground for many of the computer programs developed, such as those examining air/sea turbulence interactions, current patterns, sediment transport, fog dynamics, etc.

A. THE OBJECTIVE OF THE STUDY

The objective of the investigation was to identify, map and quantify a representative sampling of the benthic algal species within the Del Monte Beach kelp bed.

B. RÉSUMÉ OF RELATED RESEARCH

It has now been nearly thirty years since Andrews (1945), using hard hat diving equipment, published first-hand observations of the Macrocystis holdfast communities in Monterey Bay. McLean (1962), at Granite Point, and Faro (1969), off Pt. Pinos (Fig. 1), were among the first Peninsula kelp bed investigators to employ SCUBA equipment for the purpose of conducting underwater biological surveys. More recently, individual investigators such as Davis (1974), Mr. Anthony Weaver of Hopkins Marine Station (personal communication) and Miss Valery Gerard, of the University of California, Santa Cruz (personal communication) have continued to expand the methodology of SCUBA supported subtidal research in employing statistical analysis techniques to permit a more sophisticated study of the local underwater environment.

Ongoing group field work on kelp canopies and associated communities as part of the central California Department of Fish and Game program has been summarized recently (Miller and Geibel, 1973). In 1971, an ambitious group subtidal field study of kelp beds between Santa Cruz and Malpaso Creek was conducted and reported on by students enrolled in an ecology course at Hopkins Marine Station (Pearse, 1971).

Of particular interest in this investigation are studies being conducted under the supervision of Dr. E. C. Haderlie at the Naval Postgraduate School (Haderlie, 1970; Haderlie, Mellor, Minter and Booth, 1974). These studies, and others planned for the future, are attempting to establish ecological

baseline data for the subtidal area of Del Monte Beach (Fig. 2), with the purpose in mind of comparing biotic communities and environmental conditions prior to and after the construction of a proposed breakwater. The completion of the presently conceived breakwater would encompass much of the present day kelp bed area (Haderlie, 1970). The investigation being reported on here is intended to provide a contribution to the baseline data base.

C. METHODS

1. Underwater Survey

The underwater part of this investigation can be divided into eight phases which spanned the time interval from September 1973 to September 1974.

a. Collection of Species – First Phase

The first phase involved collection of representative species of algae. Dives commenced at the nearshore edge of the kelp bed, and then proceeded seaward by swimming on a line of bearing. Three principal areas were searched – the first between A and B transect, the second along C transect, and the third along D transect (Fig. 2). Two collection dives were devoted to each blind-cast type search within the three transect regions.

Specimens were collected only if they appeared distinct from species previously taken. Unlike the mapping phases (to be discussed) no defined plant size collection limitation was established. Large specimens were stored underwater in canvas bags, whereas smaller species were

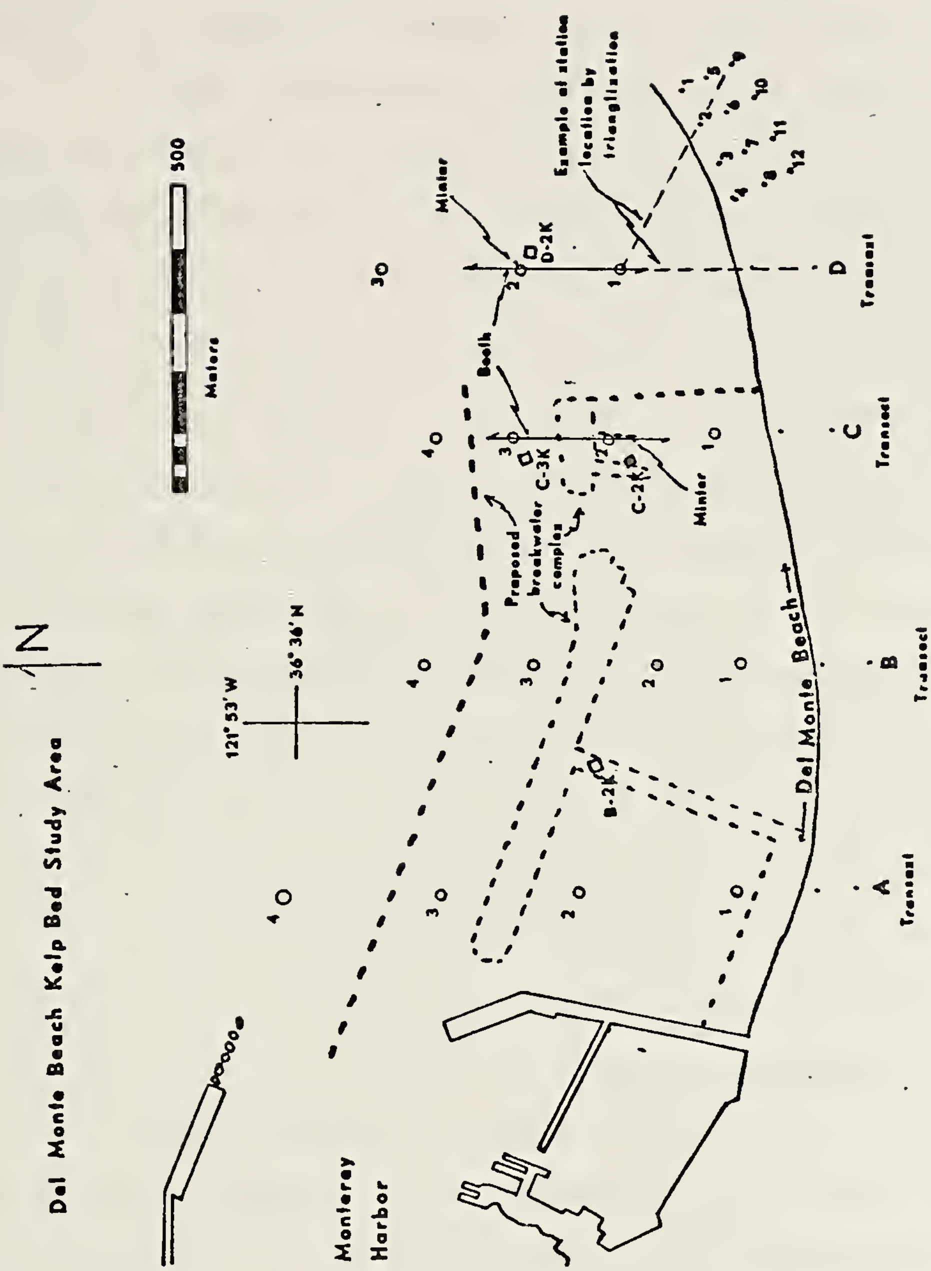

Del Monte Beach Kelp Bed Study Area
N
121°53' W
36°36' N
Meters
500
Monterey
Harbor
Proposed breakwater complex
Buoy
Example of station location by triangulation
B-2K
C-2K
C-3K
D-2K
Del Monte Beach
Transect A
Transect B
Transect C
Transect D

FIGURE 2

best maintained by insertion into a clear plastic tube with a movable cap at one end. (The tube was approximately 3.5 cm in diameter and 30 cm in length. This tube also served well as the protective container for a glass tube thermometer.)

Upon completion of each dive and while specimens were still fresh, they were examined for distinctive gross morphological characteristics that might be readily observed by a diver without visual magnification aids. A provisional identification was then attempted utilizing Smith (1969), after which the specimens were fixed in a standard 3.5% formaldehyde solution. Next, they were pressed and, if suitable, dried onto appropriate sized mounting sheets. (The largest specimens were photographed so as to avoid the need for oversized storage space.) At least one example of each species has been retained by Dr. Haderlie in an herbarium file, should future interest warrant re-examination.

b. Quadrat Sites - Selection and Construction

Once representative samples of the more common species had been collected and identified, the task of selecting representative bottom areas for mapping, commenced. Four sites were ultimately chosen on the basis of the following considerations: (i) Desirability of being within an area relevant to assessing the impact of breakwater construction on the presently undisturbed benthic biology, (ii) proximity to previous studies e.g., Minter (1971) and Booth (1971), so as to facilitate comparison of findings, (iii) favorability of being within a species diverse habitat

so as to allow more species distribution patterns to be investigated, (iv) feasibility of returning after a period of years to the identical quadrat originally investigated; thus quadrat sites were selected near transect stations that could be readily located at the surface by range markers on shore (Fig. 2), (v) necessity of operating within wave energy and depth constraints dictated by Navy Diving Manual safety rules, (vi) desirability of comparing stations sufficiently separated so as to be subject to distinctily different wave exposure.

Oosting (1956) has suggested 100 m^2 to be an adequate sample size for surveying terrestial forest tree communities. With this in mind, a 144 m^2 area (Fig. 3) was selected in order to assure a conservative representation of the local kelp forest community studied. The number of quadrats constructed (four) was limited by the one year of time available for the investigation. Once proper sites had been chosen, the construction of quadrat sites began. The initial emplacement of garden-hose buoys (Fig. 4A) attached to 45 kg cement cylinder anchors (clumps) marked one corner of each chosen quadrat location. Next, an underwater baseline was run out from the buoy clump and secured at either end into shale substrate, according to the method described by Minter (1971). Perpendicular perimeter lines to the baseline were formed by drawing taut two premarked triangle lines. Both the baseline and the perpendicular perimeter lines were made of 3/8" (9.3 cm) diameter polypropylene. Additional clumps were rolled into position to

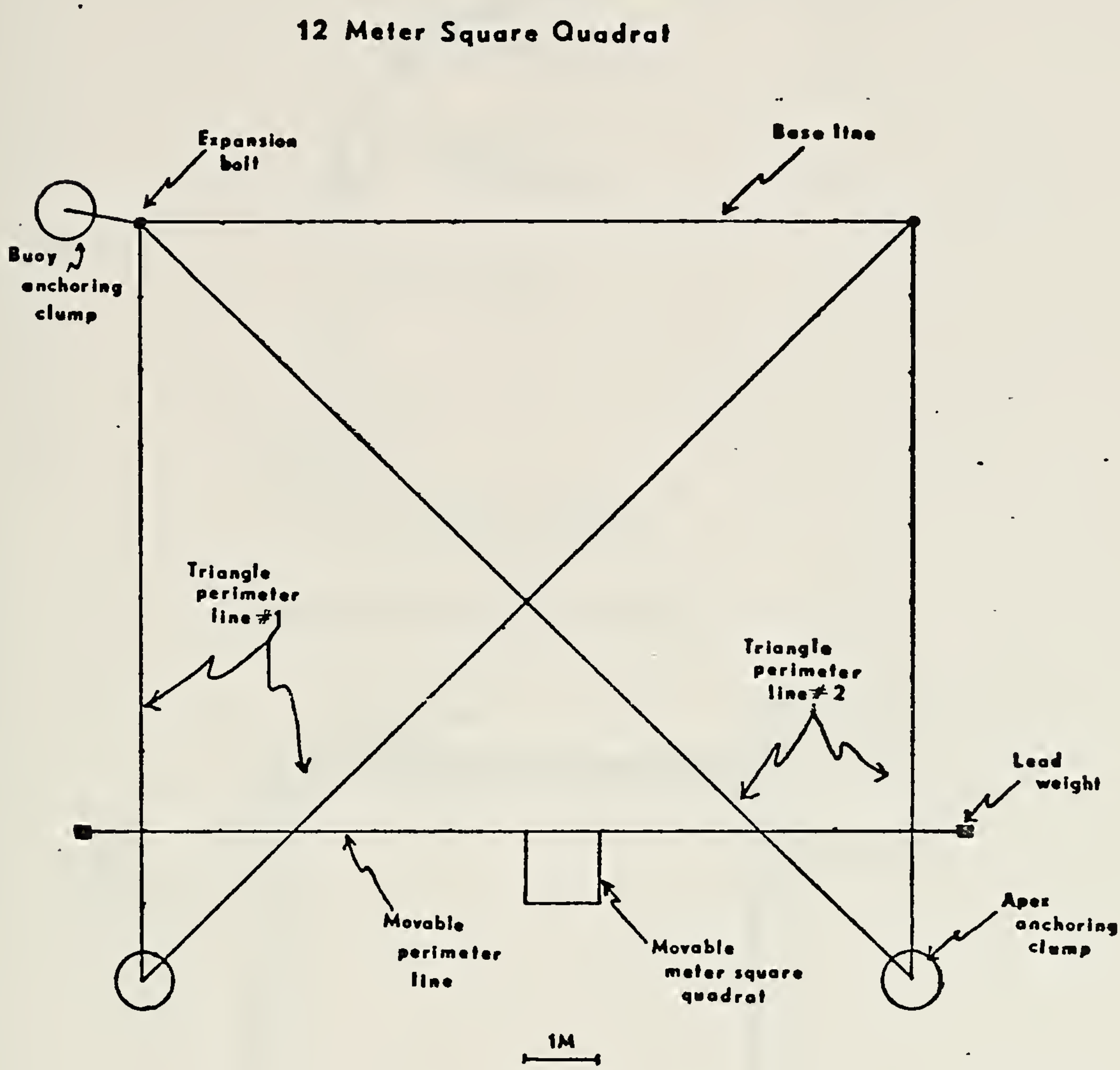

12 Meter Square Quadrat
Expansion bolt
Base line
Buoy anchoring clump
Triangle perimeter line #1
Triangle perimeter line # 2
Lead weight
Movable perimeter line
Movable meter square quadrat
Apex anchoring clump
1M

FIGURE 3

Quadrat Site Locator Buoy

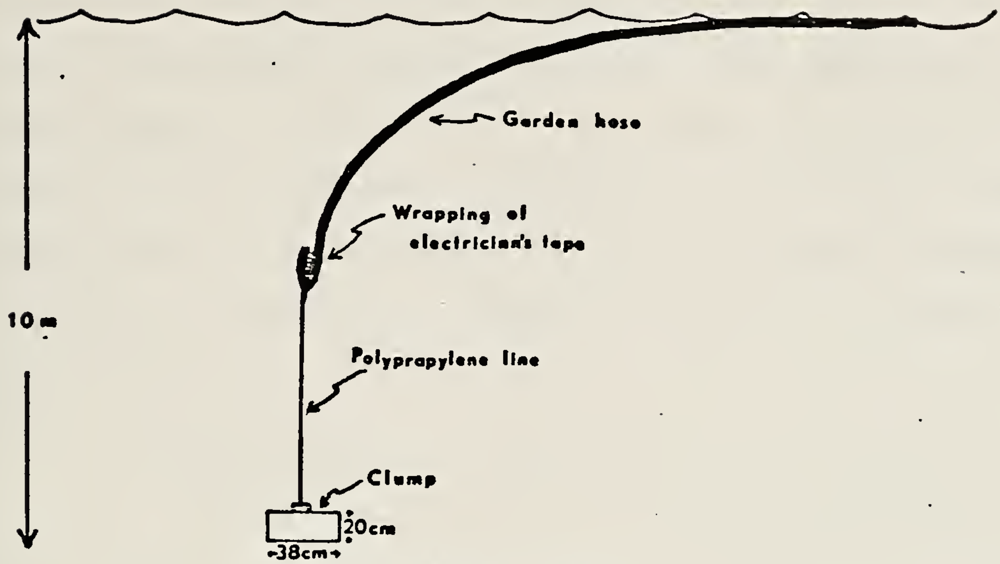


FIGURE 4A

Movable Meter Square Quadrat

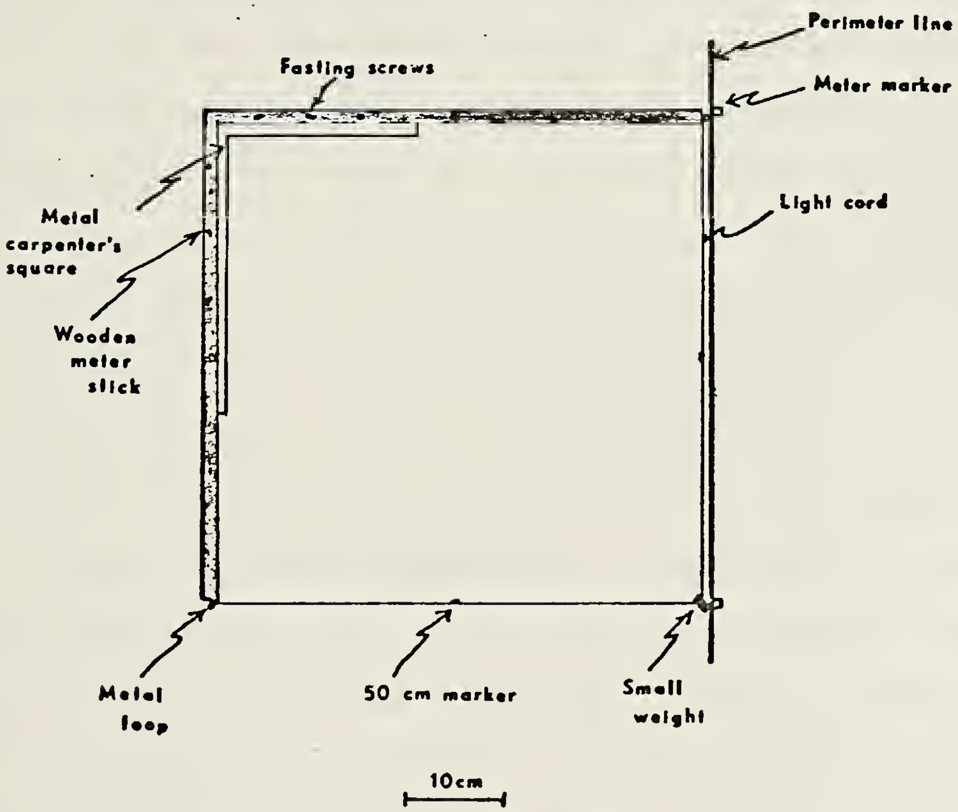


FIGURE 4B

create the required apices. Finally, a movable perimeter line was laid out. It was attached by timberline hitch knots to the two triangle formed perimeter lines and kept stretched during mapping by small lead diver weights attached at the center and at either end. All perimter lines were wrapped at one meter intervals with black electrician's tape and individually marked with U-Name-It skin diver rubber base paint.

c. Development of Underwater Survey Technique

It was necessary to set definable mapping rules before beginning the mapping process itself. Also, since the underwater ecology survey tools about to be described, were built specifically for this investigation, it was felt best to test out the various devices, e.g., the movable one meter square quadrat (Fig. 4B), prior to commencing the mapping phase. The eventual rules which were judged most suitable for this survey were as follows: (i) Algae would be counted only if they could be readily observed, being at least 7 cm in height, or covering approximately 50 cm^2 in horizontal extent. (Plants with an individual or cluster size greater than approximately 150 cm^2 in horizontal extent were given a special designation.) Size constraints were established based on the size of the investigator's index finger and thumb (Fig. 5). Only plants which exceeded the size constraints were counted. (ii) Approximately 24 m^2 would need to be counted on each mapping dive to allow viewing of all quadrats over a relatively reasonable period of time (two months). Therefore, mapping was only allowed

Semi-Quantitative, Cut-off Height/Area Estimations

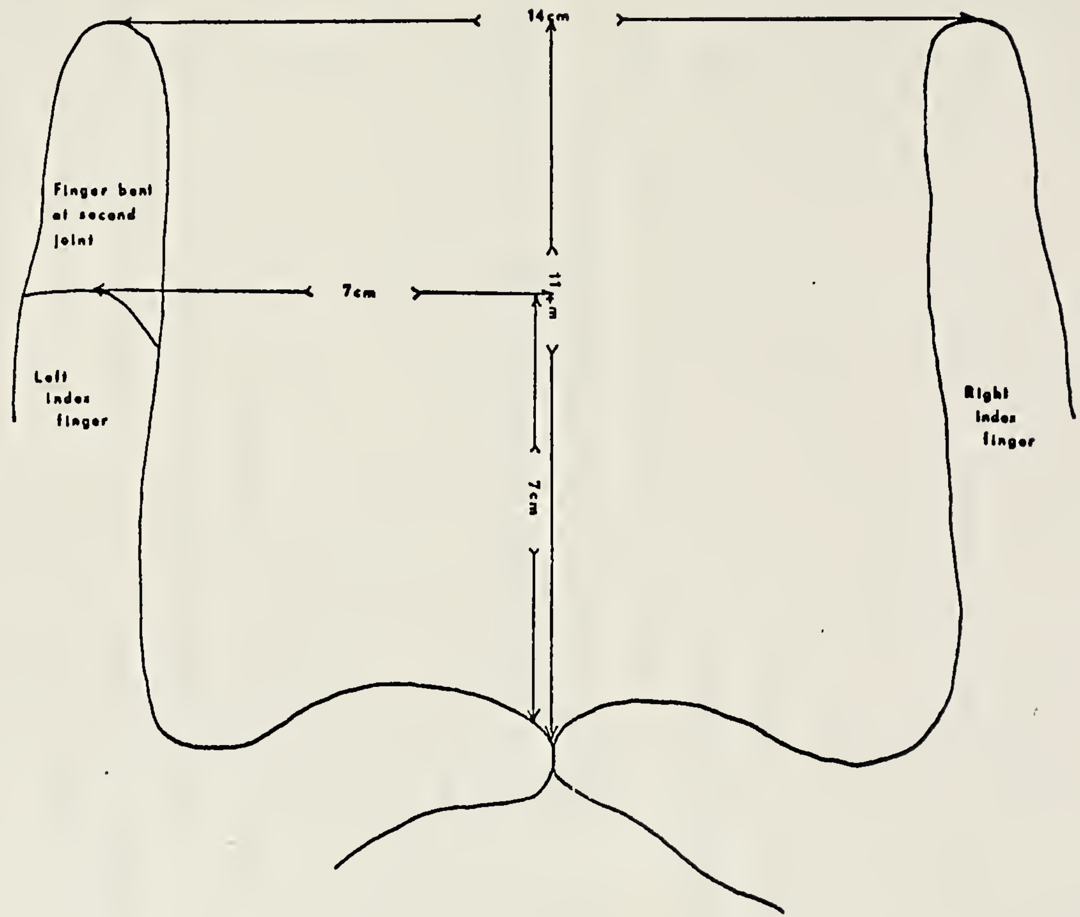


FIGURE 5

to proceed after sufficient expertise was acquired. (iii) _Macrocystis_ stipes were counted and holdfast circumferences measured by the assistant diver. The stipes were counted if they reached at least 1.0 meter above the bottom. (This was approximated by requiring the diver to kneel on the bottom and count stipes if they reached eye level.) (iv) Temperature and bottom horizontal visibility measurements were conducted prior to mapping. Temperatures were recorded 30 cm from the surface and 1.0 meter from the bottom. Bottom horizontal visibility measurements were attempted by measuring the distance a white (20 cm x 12 cm) slate could be seen as one diver slowly moved down a quadrat perimeter line, being careful not to disturb sediments.

The five mapping tools selected were: (i) a 1.0 movable meter square quadrat (Fig. 4B), (ii) a plexiglas slate (33 cm x 20 cm in dimension), paintedon one side and roughened with sand paper on both sides to permit notations with a pencil (Fig. 6), (iii) a "rust-proof" metric measuring tape (for estimating _Macrocystis_ holdfast circumferences), (iv) a second, white plastic writing slate (20 cm x 12 cm, in dimension), which served to record counts of _Macrocystis_ stipe numbers and also served as a miniature Secchi disk for the bottom horizontal visibility measurements, and (v) a canvas bag (30 cm x 20 cm, in dimension), which retained the plastic tube with enclosed thermometer, collected specimens, measuring tape, etc.

Underwater
Marking
Slate

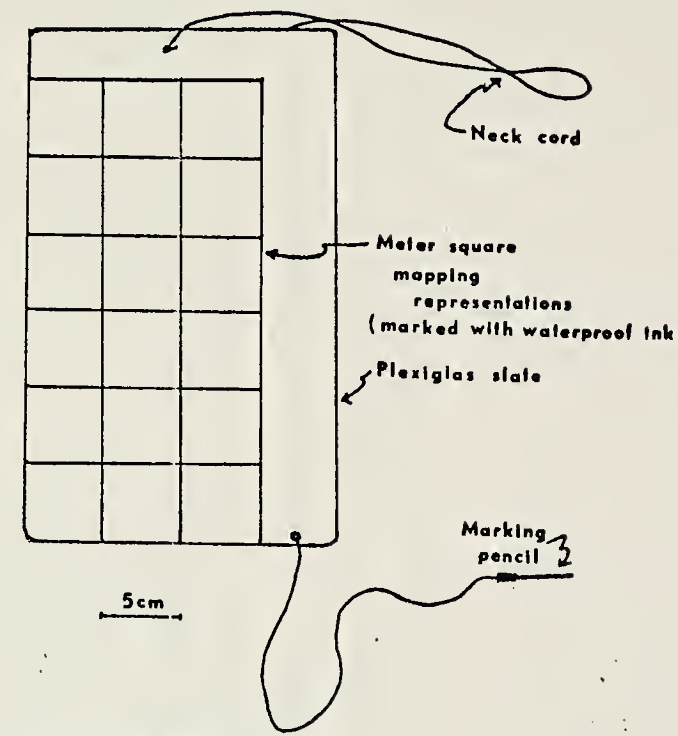


FIGURE 6

d. Mapping – First Phase

Due to the generally marginal and unpredictable weather during the winter season, it was decided that only a very limited initial mapping effort would be practical. Only Phaeophyta were studied during the first mapping phase; lack of familiarity during this mapping phase made identification unreliable for the generally smaller Rhodophyta. The initial survey was conducted at the most wave protected region, quadrat B-2K (Fig. 2).

e. Quadrat Maintenance and Repair

Storm activity brought about surge forces which in turn tore loose numerous kelp plants. Macrocystis would inevitably become entangled in either a buoyline or one of the perimeter lines and lead to considerable displacement if not complete destruction of quadrat lines. It was therefore necessary at the outset of each underwater study to examine each quadrat for possible kelp entwinement. In particular, extensive repairs were required during the late winter and early spring.

f. Quadrat Navigational Fixing

To make it possible for the quadrats to be revisited at some future time, accurate underwater navigation from a known surface position was essential. Precise navigation was accomplished by laying out underwater a measured line attached at one end to a boat dropped anchor and at the other to a quadrat corner. The boat was pre-positioned at stations located by range pole triangularization (Fig. 2)

prior to letting go of the anchor. It remained to then record underwater the distance and average compass direction from the boat's anchor to the quadrat corner so as to attain a fix (Figs. 7A-8B). (The B-2K quadrat could not be so accurately positioned since it was too far away from the range pole triangularized stations to permit a reasonably straight underwater measurement to be taken. Thus, compass bearing indications are provided for this quadrat.)

g. Mapping — Second Phase

Mapping surveys at all four stations proceeded with the coming of summer weather. This was a considerably more ambitious effort than the winter surveys and included mapping of Phaeophyta, Rhodophyta, types of substrate, location of abalone shells, and the occurrence of *Diopatra ornata* colonies (Table B1, Fig. 9 and Figs. B2-B48).

h. Species Collection — Second Phase

It was felt that a second look at the transects originally surveyed in the late fall and winter of the previous year would provide some estimate of how changeable was the algal species composition in the study area. To this end additional collection dives were made, this time including a brief survey of the flora near the Monterey Sewer Outfall. As before these dives began at the near shore edge of the kelp bed canopy and proceeded on a line of bearing seaward. Also, as in the winter collection dives, stipes of *Macrocystis* plants encountered were counted up to a maximum of 17 plants per dive (Table 5).

Quadrat Navigation Chartlets

Quadrat B-2K

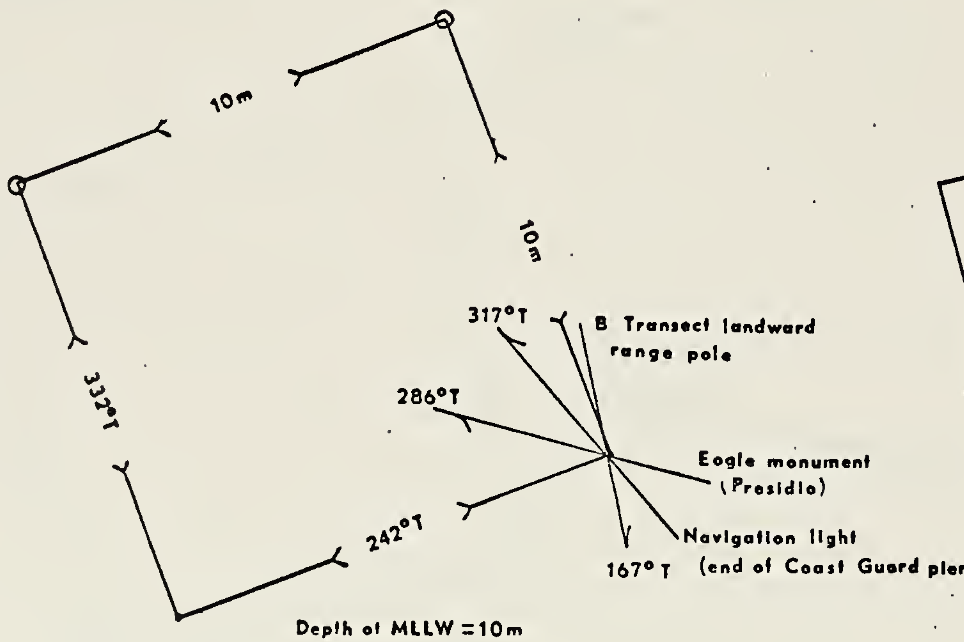


FIGURE 7A

Quadrat C-2K

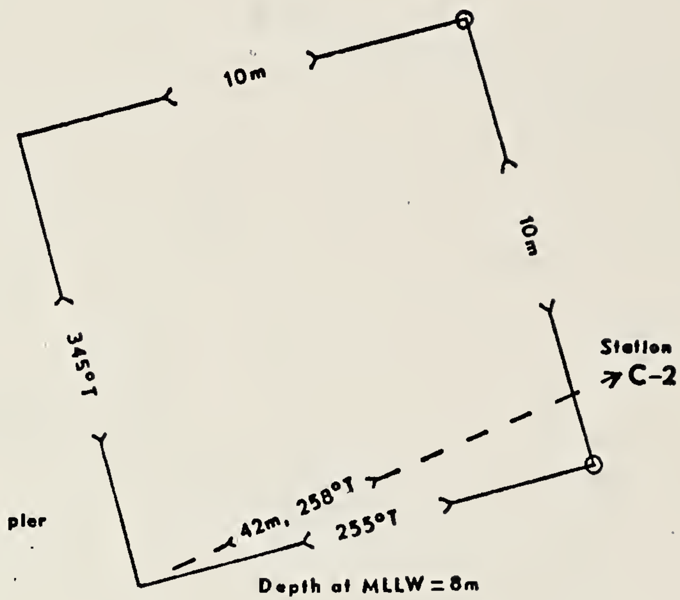


FIGURE 7B

Quadrat Navigation Chartlets

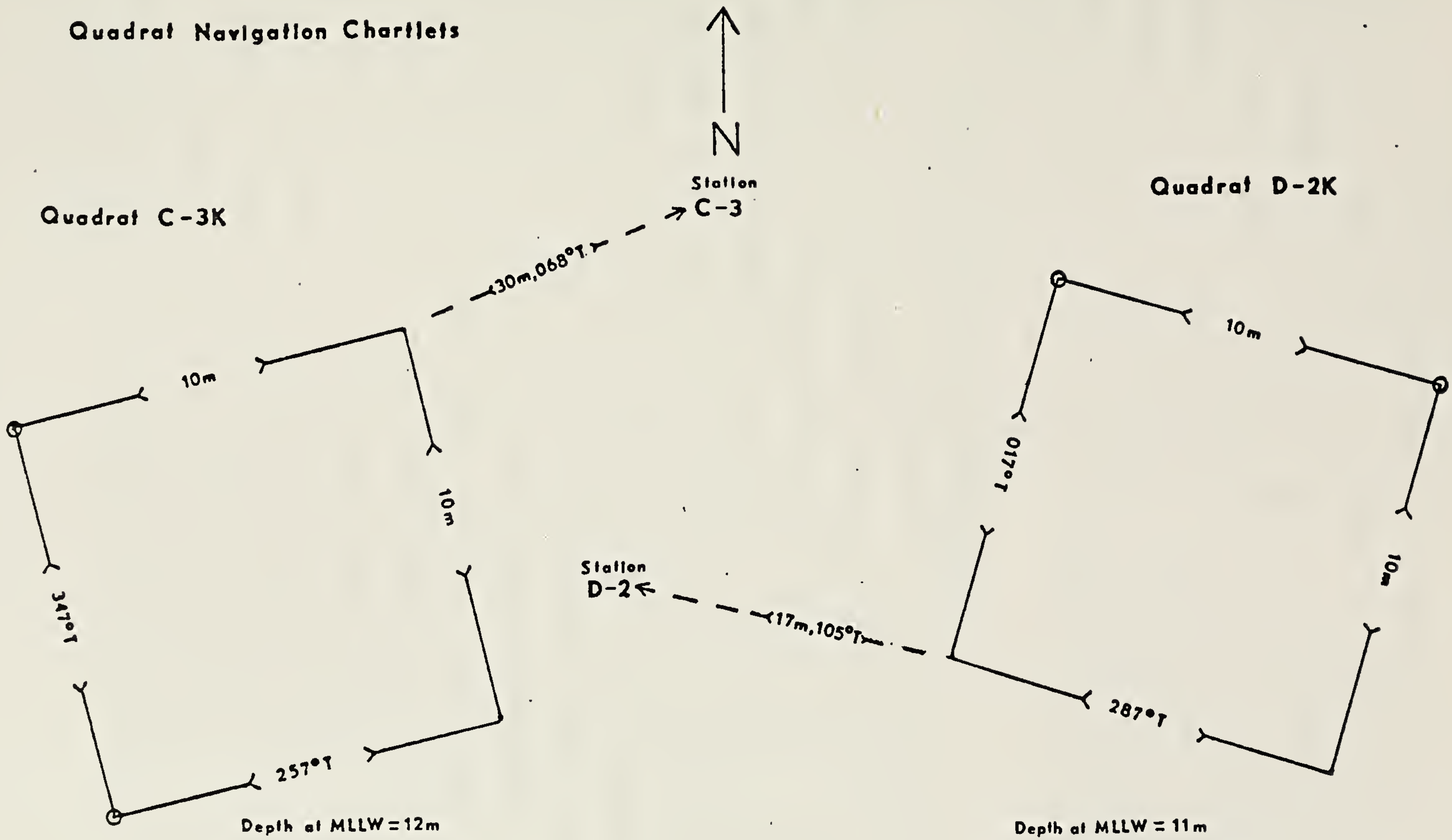


FIGURE 8A FIGURE 8B

i. Quadrat Disassembly

At the completion of the study all lines and buoys were removed from each quadrat. Although recognizing that subsequent recognition of quadrat sites would thereby become more difficult, the removal of lines was considered essential to avoid entanglement in quadrat plants. It was intended that the remaining clumps and expansion bolts would serve as adequate confirmation of quadrat outlines for divers returning to restudy the areas.

2. <u>Aerial Photograph Interpretation</u>

To supplement the underwater field study in the Del Monte Kelp bed and provide a more generalized look at the canopy structure over an extended period of time, a series of aerial photographs was collected. A 1969 photo negative of the kelp bed (Fig. 16) was provided by Mr. Jack Mellor of the Naval Postgraduate School, Oceanography Department. Copies of 1971 through 1974 photographs were made available by Mr. Doug Pirie of the U.S. Army Corps of Engineers, NASA aerial photograph library (Figs. D1-D4). The surface canopy sketches shown in this report were drawn by projecting the applicable slides onto a pre-drawn harbor outline. The pictures themselves were taken from directly overhead at altitudes of 5,000 feet and 10,000 feet (1560 m and 3060 m). The 1969 picture was taken on black and white film, the remaining photos were shot using color film with various density yellow filters.

3. Refraction Analysis

An ocean wave refraction/numerical computer program was analyzed using digitized bathymetry inputs from a rectangular area extending from the 200 fathom curve to the Monterey Peninsula coastline in one dimension and between Pt. Cypress and Fort Ord in the other (Fig. 1). The bathymetry data was compiled by interpolating soundings from C&GS Chart 5403. Originally written by R. S. Dobson (1967), the program was utilized in this study by comparing incident surface wave energy between quadrat sites (Table 9) and relating the differences in wave energy to some of the differences in species composition as observed during the underwater investigation.

II. RESULTS OF THE INVESTIGATION

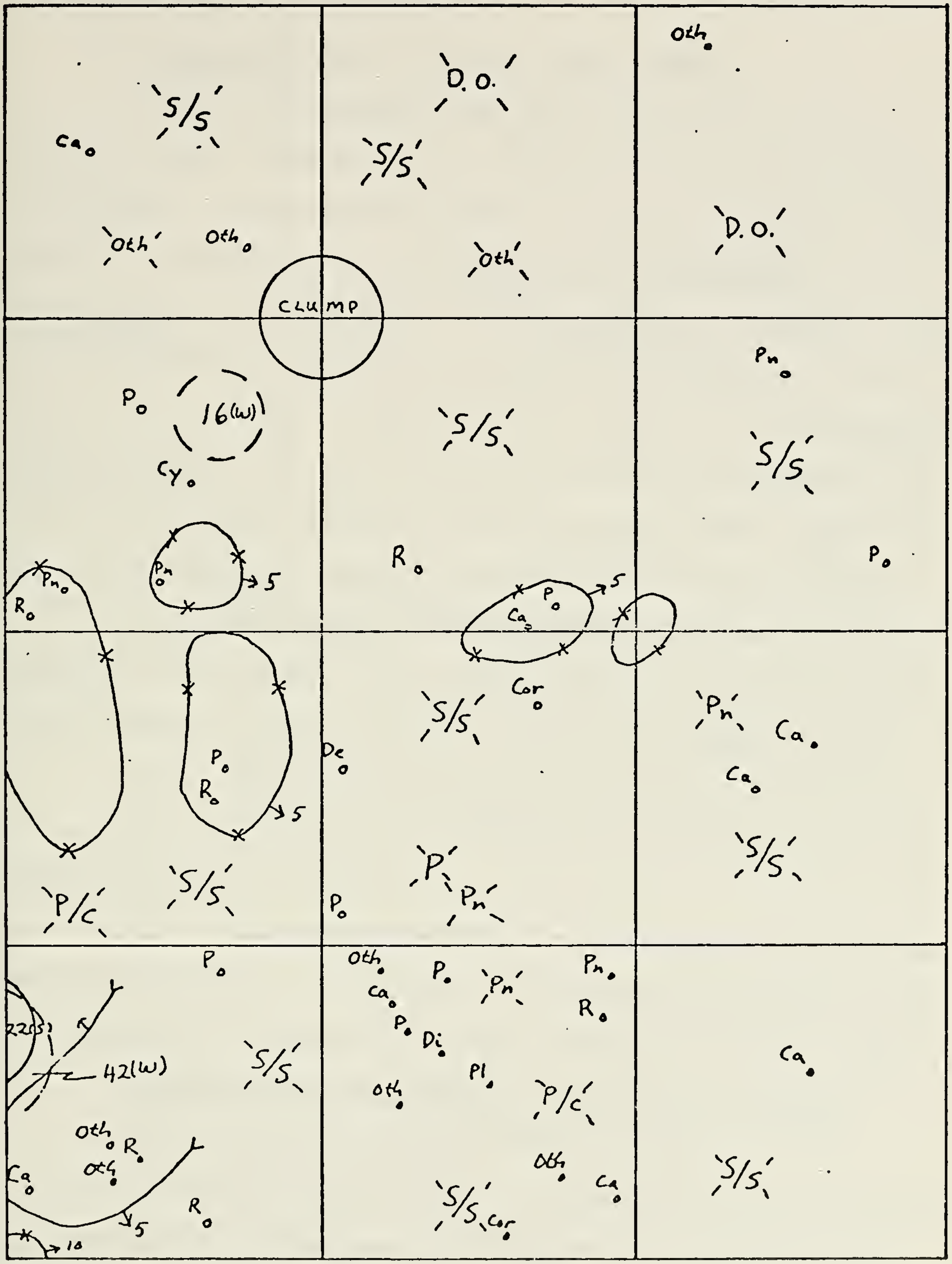
A. UNDERWATER SURVEY

1. Species List

The species list compiled (see Table A) is based upon identifications confirmed by Dr. Isabella Abbott, of Hopkins Marine Station, with the exception of those with an asterisk before the name. These species were either identified with assistance from Bud Laurent of the California Department of Fish and Game, or from Dr. Tom Thompson and Scott Kimura of the Moss Landing Marine Laboratories.

Below each species name are abundance adjectives based on field notes taken for each dive. If a species was seen only once in all dives, it was considered "rare." If it was observed only two or three times it was designated "scarce." The remaining species were listed as "common" unless found on all but two or three dives. In such cases they were noted as being either "abundant," or if seen on all but one or every dive, "very abundant." The location within the kelp bed of each species observed and examples of substrates to which a species was found attached, were recorded respectively following the abundance adjective. A brief species (or genus if appropriate) description was compiled to complete the species listing. The descriptions are based on those specimens taken during the investigation. The pictorial subarea maps (Fig. 9 and Figs. B2-48) are

Example Quadrat Pictorial Subarea Map ← 1M →



B-2K FIGURE 9 P-1

catalogued in sequential order according to the arrangement shown in Fig. B1.

2. Quadrat Pictorial Subarea (12 m^2) Maps

Symbols employed for use in the quadrat pictorial subarea maps are described in Table B. As can be recognized in Table B, no attempt was made to distinguish between various species of a genus, e.g., *Callophyllis flabellulata* vs. *C. heanophylla* vs. *C. pinnata* vs. *C. thompsonii*, although usually one species was eventually determined by consecutive collections to be far more abundant than others, e.g., *Callophyllis flabellulata* proved to be by far the most common species of the aforementioned group. Some of the other more important mapping assumptions implied in the subarea maps are that:

(i) The substrate was uniformly flat, and without variation in texture, i.e., smooth shale, fractured shale, pholad riddled shale — all were classified simply as shale.

(ii) Degree of slope of ledges was not indicated.

(iii) Depth was not considered in denoting any shale areas covered by sediments.

(iv) *Macrocystis* holdfast circumference measurements were symbolically indicated as circular areas which generally only crudely approximated the true holdfast perimeter shape.

3. Quadrat Numerical Diagrams (Five Floral Groups)

The frequency of algae symbols displayed in the quadrat pictorial subarea maps were summarized quantitatively in four numerical diagrams (one diagram per quadrat), and classified as belonging to one of five groups:

Group (1) *Macrocystis* (surface canopy Phaeophyta)

Group (2) *Cystoseira*, *Desmarestia*, *Dictyoneuropsis*, and *Pterygophora* (understory Phaeophyta)

Group (3) *Callophyllis*, *Laurencia*, *Plocamium*, *Rhodymenia*, and other unidentified species (non-coralline Rhodophyta)

Group (4) *Bosiella*, *Corallina* (articulated coralline Rhodophyta)

Group (5) *Peyssonelia*, *Pseudolithophylum* (crustose coralline Rhodophyta)

Each of the above groups represents a horizontal row in the quadrat numerical diagrams (Fig. 10). These groups were arranged principally for taxonomic discrimination but also with an eye toward being compatible with Neushal's layered kelp community concept (North, 1971). The five floral group arrangement can be roughly interpreted in terms of a logarithmic adult height distribution viz., Group 1 = 10-20 m, Group 2 = 1-2 m, Groups 3 and 4 = .1 m to .2 m, and Group 5 = approximately .001 m. (Although a number of Rhodophyta were collected which could have comprised a .01 to .02 m height group (e.g., *Pleonosporium*, *Pterosiphonia*), underwater identification difficulties precluded this possibility since such forms rarely acquired sufficient area extent to be counted.)

The combined absolute and relative frequencies of occurring algae symbols within each group were compared between the four quadrats (Table 1). Of particular interest

Quadrat Numerical Diagrams (Five Floral Groups)

B-2K

1	11/10				
2	1/3	1/2	15/19	X/X	
3	76	3	1	39	109
4	31	4	85	9	
5	64	16	27	57	

C-2K

1	18				
2	7	X	10	X	
3	10	X	1	63	7
4	353	81	5	1	
5	61	X	89	49	

C-3K

1	12				
2	80	X	76	X	
3	50	13	66	89	9
4	57	46	X	X	
5	106	4	256	54	

D-2K

1	26				
2	4	X	7	1	
3	3	X	3	58	4
4	328	75	73	2	
5	51	2	33	77	

FIGURE 10

KEY

The numerical diagrams above display the total number of occurrences of the algae symbols (table B) mapped in each quadrat.

Note (1): In B-2K, upper numbers refer to winter values, lower numbers refer to summer values.

Note (2): X indicates genus not observed in quadrat.

Row (1): *Macrocystis* holdfasts
Row (2): *Cystoseira*, *Desmarestia*, *Dictyoneuropsis*, *Pterygophora*
Row (3): *Callophyllis*, *Laurencia*, *Plocamium*, *Rhodymenia*, Other non-coralline Rhodophyta
Row (4): *Bosiella*, *Bosiella* large area, *Corallina*, *Corallina* large area
Row (5): *Peyssonelia*, *Peyssonelia* large area, *Pseudolithophylum*, *Pseudolithophylum* large area

TABLE I

Quadrat Comparisons of Grouped Population Frequency Data

(Numbers outside parentheses refer to absolute population frequencies, those inside parentheses refer to relative frequencies.)

Algae Group / Quadrat	B-2K Winter	B-2K Summer	C-2K	C-3K	D-2K
Macrocystis, Total # Holdfasts	11	10(1.8%)	18(2.4%)	12(1.3%)	26(3.5%)
Total # Understory Phaeophyta	17	24(4.3%)	17(2.2%)	156(17.0%)	12(1.6%)
Total # Non-coralline Rhodophyta	Not Counted	228(41.2%)	81(10.7%)	227(24.6%)	68(9.1%)
Total # Articulated Corallines	Not Counted	129(23.2%)	440(58.2%)	103(11.2%)	478(64.1%)
Total # Crustose Corallines	Not Counted	164(29.6%)	199(26.4%)	420(45.8%)	163(21.8%)

are: (i) the apparent group by group similarity between quadrats C-2K, (ii) the singularly high frequencies of understory Phaeophyta and crustose corallines at C-3K, and (iii) the nearly equal frequency of non-coralline Rhodophyta at B-2K and C-3K.

4. Four Substrate Types

Figures 11-14 illustrate the four types of substrate analyzed as part of this investigation. They were classified as: (i) shale Ledge Edge Areas (LEA), defined as that horizontal portion of a ledge with a width spanning between the edge to 20 cm from the edge. (ii) Large Scale Sand Covered Shale Areas (LSSCSA), defined as that observed shale area at least 16 square meters in area with at least a fifty percent sand or sand and shell covering. Sand depths were not measured. (iii) *Macrocystis* Holdfast Near Field Areas (MHNFA), defined as that region within an annulus extending from the base of the *Macrocystis* holdfast to 20 cm from the holdfast. (A few holdfasts were attached to large annelid tube worm mounds whose circumference extended beyond that of the holdfast; no measurement adjustment was made for such phenomena.) (iv) Remaining Area (RA), defined as all remaining substrate areas not previously classified. Actually, this area was calculated by subtracting the total LSSCSA, LEA, and MHNFA, from the total quadrat area. For this reason the resulting Remaining Area value is somewhat in error, since there is actually some overlap among the other substrate type areas; the Remaining Area values are perhaps as much as ten percent less than what they would be if all overlapping areas were

The Four Types of Substrate Studied at Quadrat B-2K

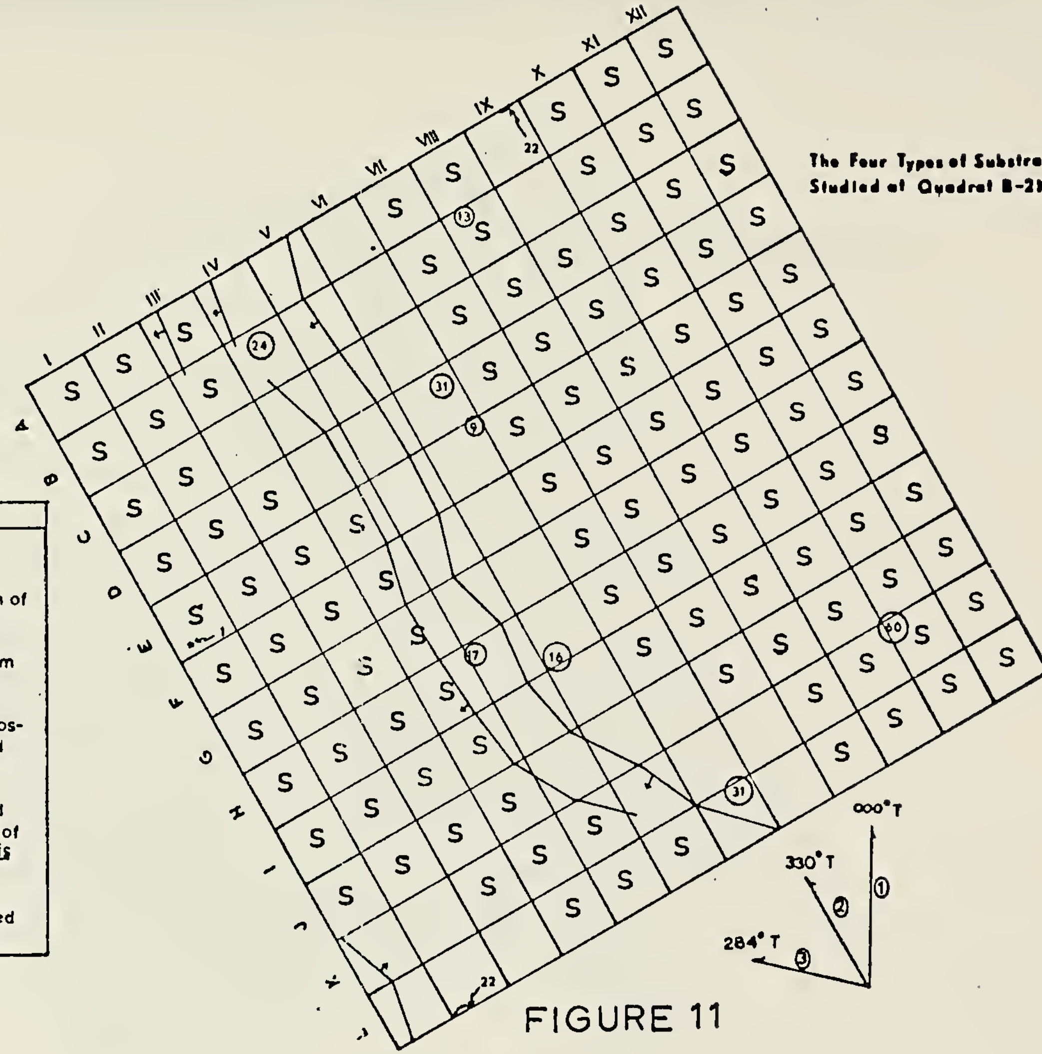


FIGURE 11

KEY TO SYMBOLS

Symbol	Explaination
1	True North
2	Trending orientation of local fault zones.
3	Orientation of bottom contour.
S	Meter squares composing Large Scale Sand Covered Areas.
12	Location, circularized circumference and # of stipes of *Macrocystis* Near Field Areas.
	Linearly approximated Ledge Edge outlines

The Four Types of Substrate Studied at Quadrat C-2K

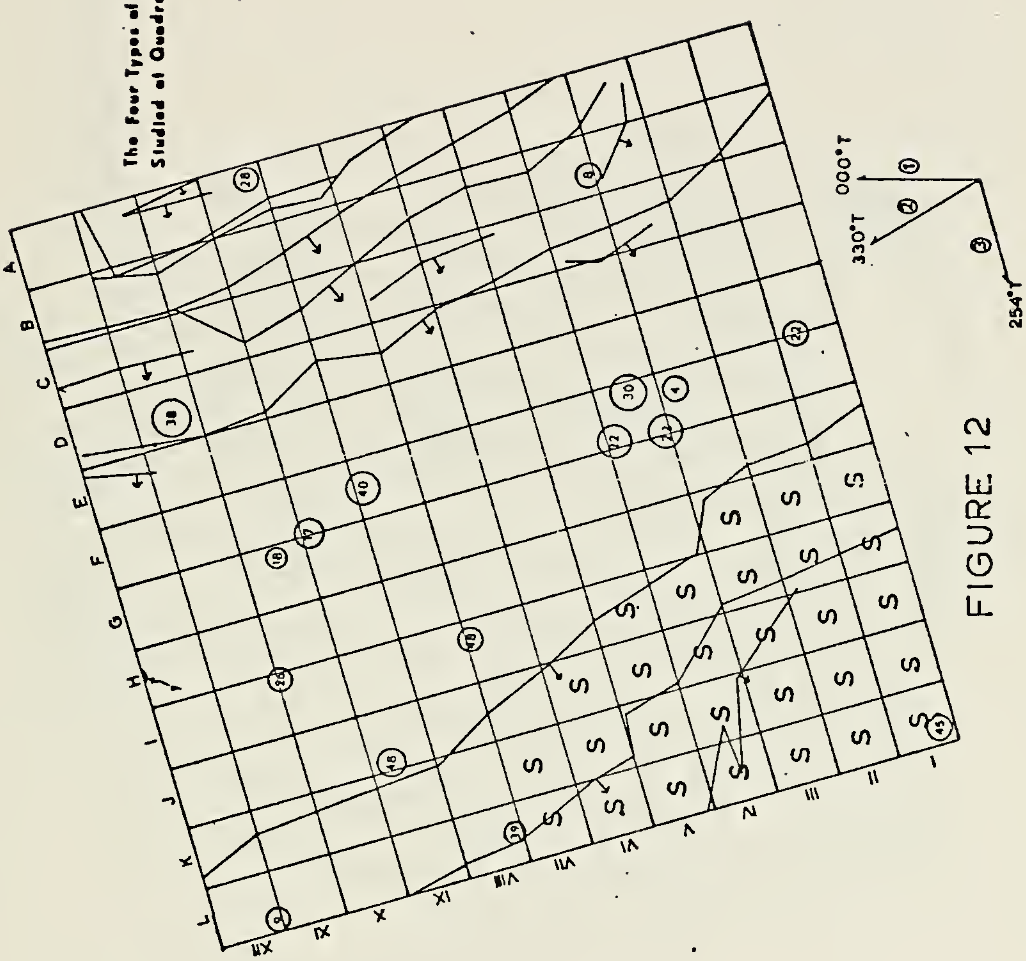


FIGURE 12

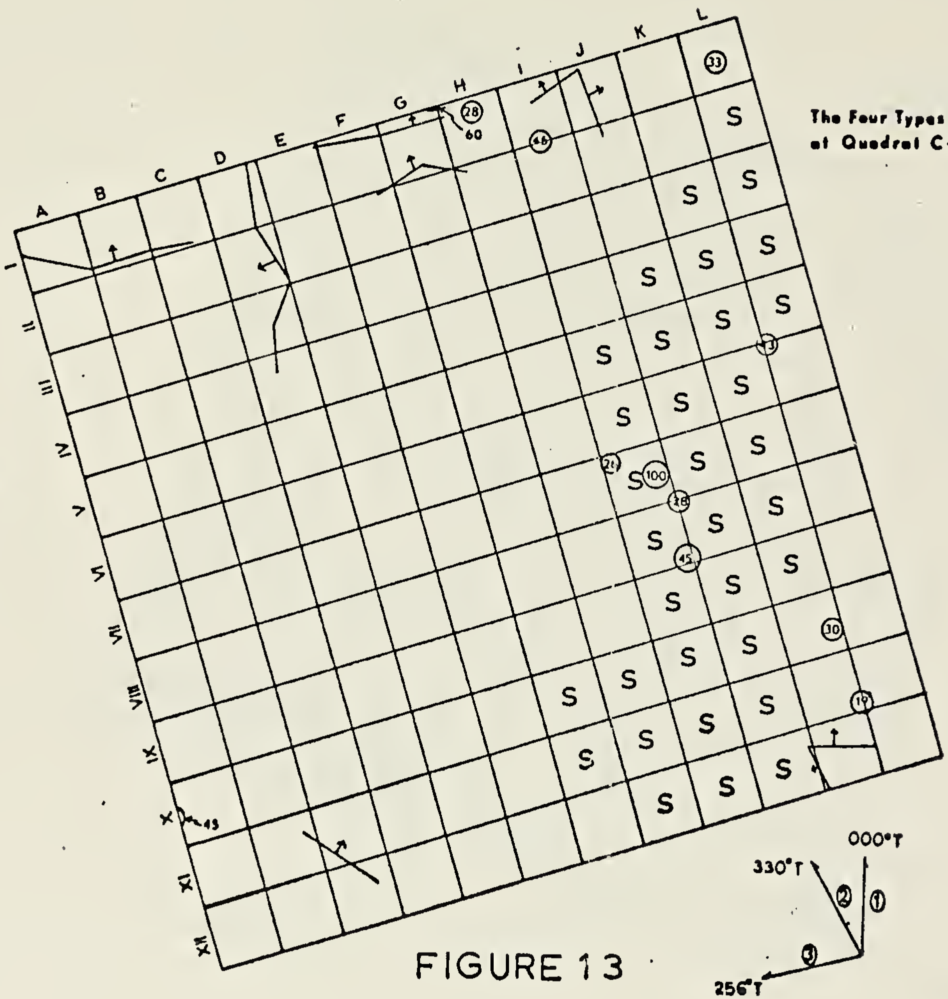
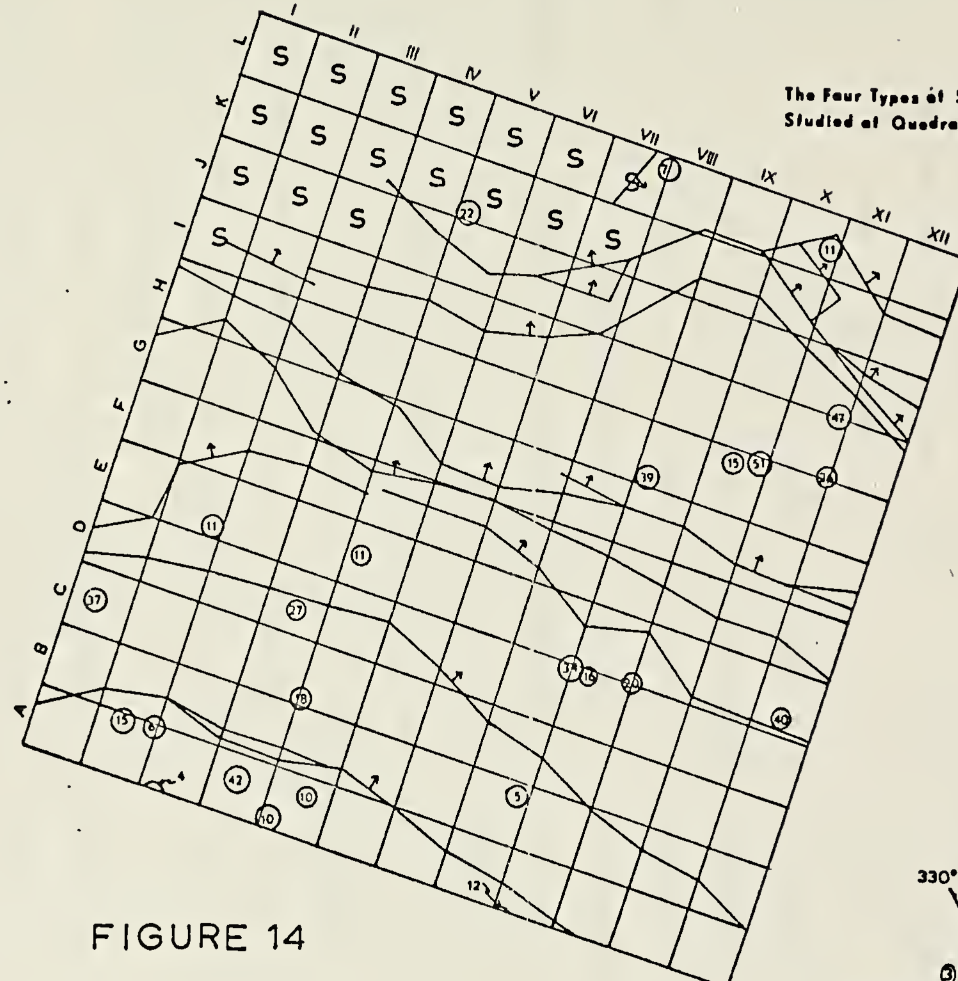


FIGURE 13

The Four Types of Substrate Studied at Quadrat C-3K

The Four Types of Substrate
Studied at Quadrat D-2K



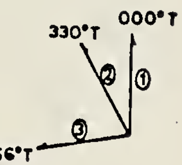


FIGURE 14

subtracted out. Table II summarizes and compares the measured areal extent of each substrate type in the four quadrats. It may be noted that C-2K and D-2K have a similar substrate type distribution. B-2K has by far the greatest Large Scale Sand Covered Area and C-3K is most dominated by substrate classified as Remaining Area.

5. Floral Density and Chi-Square Computations

By summing the total number of symbols belonging in each of the five floral groups over all four quadrats and then dividing by the total four quadrat area (576 square meters), computed floral density values were obtained. Similarly, density values within each of the four substrate type areas were determined (Table III). It is apparent by studying this table that when compared to the total substrate area considered, the floral densities of all groups are less in the Large Scale Sand Covered Shale Area type substrates, and greater in the Ledge Edge Areas. In *Macrocystis* Holdfast Near Field Areas however, the five groups do not display a uniform density difference compared to those found within the entire substrate area.

A chi-square test was computed to ascertain the statistical significance of the difference between floral group densities in the four defined substrate type areas as compared to the density of each group in the total 576 m^2 substrate area. In order to avoid ratio comparisons, density values were converted to frequency values prior to computing the chi-square statistics (Table IV). The observed values in Table IV correspond to the frequencies of each

TABLE II

Quadrat Comparisons of the Four Substrate Types

Quadrat / Type Substrate	LSSCSA(1)	LEA(2)	MHNFA(3)	RA(4)	TA(5)
B-2K	106*	6	4	28	144
C-2K	28	16	10	90	144
C-3K	33	4	3	104	144
D-2K	18	21	8	97	144
Total (Total %)	185(32%)	57(10%)	25(4%)	319(55%)	576(100%)

*(values are in m^2)

Key to Substrate Abbreviations

(1) Large Scale Sand Covered Shale Area

(2) Ledge Edge Area

(3) _Macrocystis_ Holdfast Near Field Area

(4) Remaining Area

(5) Total Area

Note (A): The area values listed above were obtained from measurements of the quadrat pictorial subarea maps.

Note (B): TA = LSSCA + LEA + MHNFA + RA

Note (C): For further explanation of substrate abbreviations see Results of the Investigation.

TABLE III

Totals of Grouped Population Density Data

Algae Groups / Substrate Type	LSSCSA*	LEA	MHNFA	RA	TA*
Macrocystis Holdfasts	$\frac{10}{185}$, (.05)**	$\frac{11}{57}$, (.23)	N/A	$\frac{45}{309}$, (.15)	$\frac{66}{576}$, (.12)
Understory Phaeophyta	$\frac{25}{185}$, (.14)	$\frac{38}{57}$, (.82)	$\frac{0}{25}$, (0)	$\frac{223}{309}$, (.72)	$\frac{286}{576}$, (.53)
Non-calcareous Rhodophyta	$\frac{153}{185}$, (.83)	$\frac{116}{57}$, (2.47)	$\frac{11}{25}$, (.42)	$\frac{296}{309}$, (.96)	$\frac{576}{576}$, (1.0)
Articulated Corallines	$\frac{122}{185}$, (.66)	$\frac{353}{57}$, (7.52)	$\frac{56}{25}$, (2.16)	$\frac{619}{309}$, (2.0)	$\frac{1150}{576}$ (2.14)
Crustose Corallines	$\frac{138}{185}$, (.75)	$\frac{156}{57}$, (3.3)	$\frac{70}{25}$, (2.7)	$\frac{582}{309}$, (1.88)	$\frac{946}{576}$, (1.64)

*For explanation of substrate abbreviations see Table V.

**Values are total number of plants divided by total area of substrate type. Numbers inside parentheses are quotients of adjoining fractional values.

TABLE IV

Chi-Square Statistical Significance Tests

Algae Groups \ Substrate Types		LSSCSA*	LEA	MHNFA	RA
<u>Macrocystis</u> Holdfasts	Observed	= 10	O = 11	N/A	O = 45
	Expected	= 21	E = 5		E = 37
	Chi-Square	= 5**	χ^2 = 6		χ^2 = 2
Understory Phaeophyta		O = 25	O = 38	O = 0	O = 223
		E = 97	E = 25	E = 14	E = 164
		χ^2 = 53	χ^2 = 6	χ^2 = 13	χ^2 = 21
Non-calcareous Rhodophyta		O = 153	O = 116	O = 11	O = 296
		E = 193	E = 49	E = 27	E = 309
		χ^2 = 8	χ^2 = 90	χ^2 = 9	χ^2 = 0
Articulated Corallines		O = 122	O = 353	O = 56	O = 619
		E = 396	E = 101	E = 56	E = 666
		χ^2 = 190	χ^2 = 630	χ^2 = 0	χ^2 = 3
Crustose Corallines		O = 138	O = 156	O = 70	O = 582
		E = 304	E = 77	E = 43	E = 507
		χ^2 = 90	χ^2 = 80	χ^2 = 16	χ^2 = 11

*For explanation of abbreviations see legend, Table V.

**Computations assumed one degree of freedom, and that Yate's continuity correction was applicable. A chi-square value of at least 3.8 is considered significant at the 95% confidence level, a value of at least 6.6 is considered highly significant at the 99% confidence level.

group occurring in the four different substrate type areas. The expected values are those hypothetical frequencies a group would have in each substrate type area if each substrate type had the same group population density value as the density value found in the total substrate area.

6. Macrocystis Stipe Data

Table V displays *Macrocystis* stipe data collected from the surveyed quadrats during the course of this investigation. As can be noted, quadrat D-2K besides containing the most holdfasts (26), also retained the greatest total number of stipes, and thus the highest *Macrocystis* stipe density per quadrat area. However, quadrat C-3K contained the highest mean value of *Macrocystis* stipes per number holdfasts present; one exceptionally proliferous plant holdfast (or combination of plants with one apparent holdfast) with one hundred stipes was found in this quadrat. Unexpectedly, in comparing B-2K (W) and B-2K (S) data, both the total number of stipes and the mean number of stipes per plant indicated a substantial seasonal decline.

Figure 15 is a relative frequency graph comparing the number of stipes counted per plant holdfast during the same winter period (Jan/Feb) and summer period (Jul/Aug) as in the B-2K quadrat study mentioned above. However, the data comprising Figure 15 was obtained during species collection dives and thus represented a different sampling population from the plants studied in the quadrats. If one assumes two plant categories, i.e., 0-20 stipe plants being juveniles, and 21 or more stipe plants being older generation (terminology adapted from North, 1971), it can be seen that the data represented in Fig. 15 shows more stipes per juvenile and older generation plant were to be found in the winter sample than in summer. The underlying reasons for this apparent decline in stipe numbers is probably not due

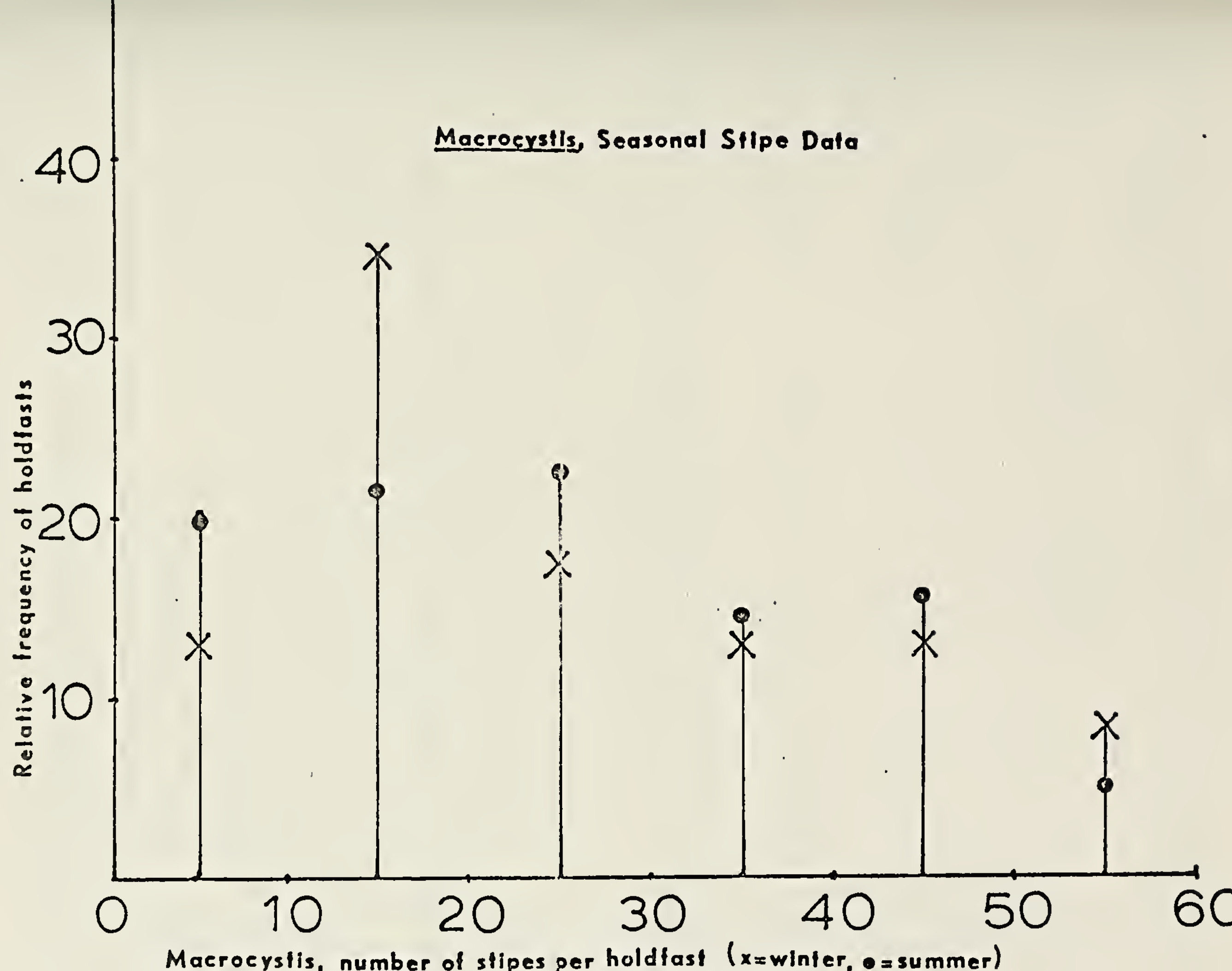

Macrocystis, Seasonal Stipe Data
40
30
20
10
Relative frequency of holdfasts
0
10
20
30
40
50
60
Macrocystis, number of stipes per holdfast (x=winter, •=summer)

FIGURE 15

TABLE V

Macrocystis Stipe Data

Stipe Data / Quadrat	B-2K (Winter)	B-2K (Summer)	C-2K	C-3K	D-2K
Total # Stipes Per Plant	332	219	443	502	518
Mean # Stipes Per Meter of Quadrat	2.3	1.5	3.1	3.5	3.6
Mean # Stipes Per Holdfast	34.6(11)*	25.5(10)	26.0(18)	49.2(12)	21.0(26)

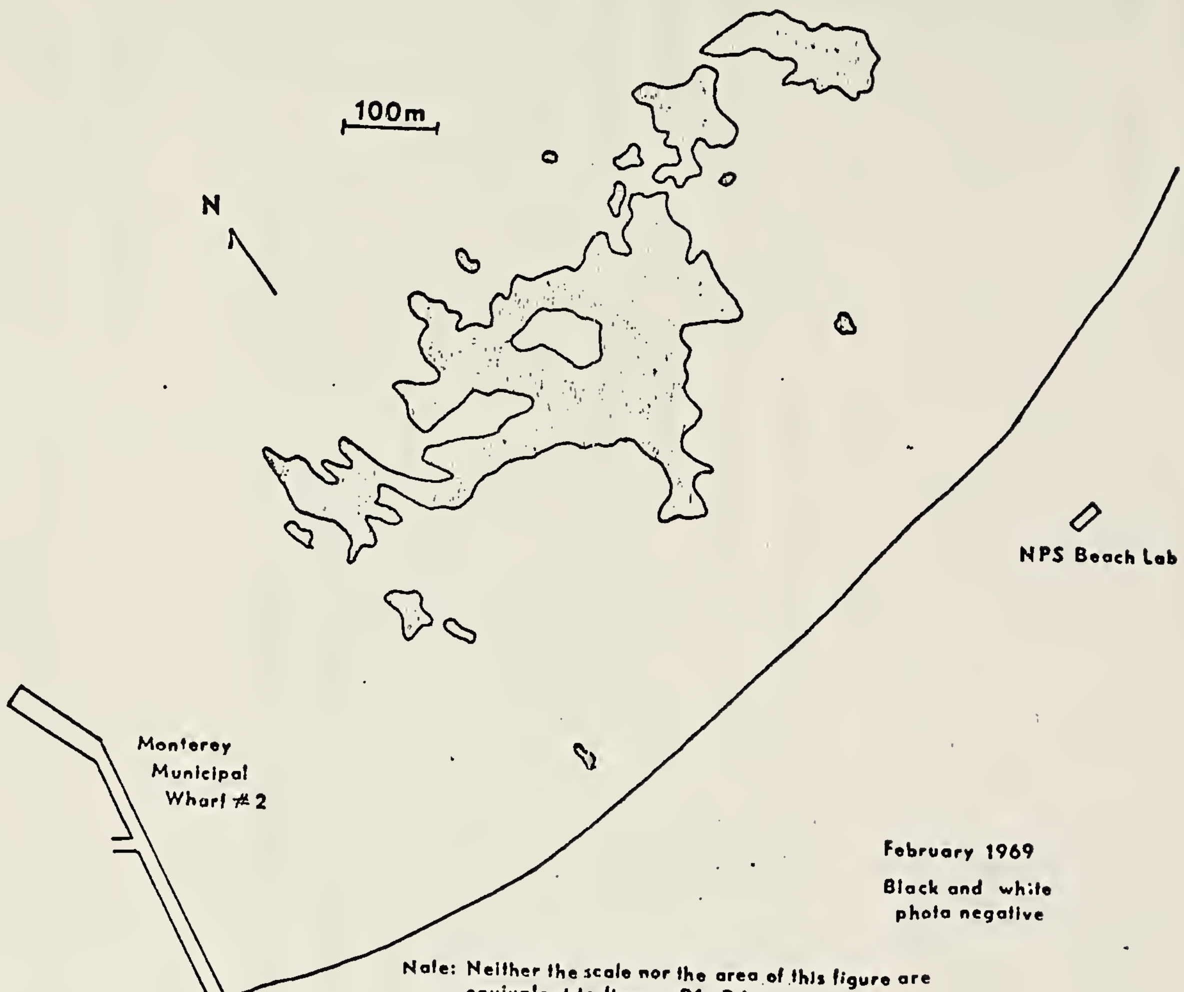
*Numbers in parentheses refer to frequency of Macrocystis holdfasts mapped in the quadrat specified.

to the same factors as the decline in numbers noted at B-2K. One would expect to encounter fewer summer stipes per holdfast in sampling by the blind cast technique which was used during the species collection dives since more young plants would be likely to establish themselves in a calmer (summer) season. Why, in quadrat B-2K, a Macrocystis with, for example, 42 stipes in winter would only have 22 stipes in summer (Fig. 9) is not understood although herbivore predation might be one explanation.

B. AERIAL PHOTOGRAPH INTERPRETATION OF KELP CANOPY

Kelp surface canopy outlines, between the period from February 1969 to January 1974, are shown in Fig. 16 and Figs. D1-D4. A considerable canopy increase between October 1971

Example Aerial Photograph of the Del Monte Kelp Bed



Note: Neither the scale nor the area of this figure are equivalent to figures D1–D4.

FIGURE 16

and December 1972 is easily recognized; the 1972 kelp bed outline has remained substantially the same in the subsequent traced photo drawings of September 1973 and January 1974. Worthy of particular mention is the persistently receding outline of surface canopy neighboring the City of Monterey's sewer outfall surface boil. Again the most perceptible change seems to have occurred between 1971 and 1972. In this instance, it may be relevant to point out that the City of Monterey shifted from primary to secondary sewage treatment beginning in the summer of 1970.

A wide, kelp-free channel approximately 350°T from the sewer treatment tanks is distinctly visible in all but the 1969 photo. (This area was not within the field of view of the 1969 photo.) A large and deep sand plain easily observed underwater is considered responsible for this absence of visible kelp (Anthony Weaver, personal communication). Observations of Figs. D2-D4, especially on the western edges of the two main canopies, seems to betray a kelp favored, elongated underlying substrate formation, trending northwest/ southeast.

C. REFRACTION ANALYSIS

Table VII provides information on the variation of wave heights to be theoretically expected assuming a single period and direction of incoming wave energy at each of the four quadrat sites (Fig. 17). It is apparent by noting the wave height values, that the wave energy theoretically increases in the quadrat order B-2K, C-3K, C-2K, D-2K. This was

consistent with the observed distribution of particular flora such as _Zostera_ which was only found in the quietest waters near the harbor area, (the largest least damaged _Cystoseira_ and _Dictyoneuropsis_ plants were also observed in this region). In contrast, _Pterygophora_ was found only in the D transect region and _Nereocystis_ could only be sighted (in small numbers) growing on the shoreward edge of the kelp beds in the vicinity of the Monterey sewer outfall. These are regions where appreciably more wave energy persists.

III. DISCUSSION

A. SOURCES OF ERROR - DIFFICULTIES ENCOUNTERED

1. Underwater Survey

The species list (Table A) should be evaluated as merely representative since it was not feasible to conduct a thorough investigation of the Del Monte Beach kelp bed in the time allocated for the underwater research phase. The entire kelp bed region beyond 16 m depth was not visited and only one short dive took place in the kelp beds near the Monterey sewer outfall.

Positive underwater species identification was virtually impossible. This was especially true of crustose algae. To overcome the difficulty of identifying the crustose algae, a large number of forms were collected over a series of dives and the great majority found to belong to one of two genera viz., Pseudolithophylum or Peyssonelia. Since these two genera could easily be distinguished by color, it was assumed that all crustose algae classified underwater would be considered as belonging to either of these two classifications. Known examples of erroneous classification due to this technique included identifying Bosiella crusts (which had not yet developed erect branches) as Pseudolithophylum and identifying Lithodura as Peyssonelia.

A second source of error in mapping can be attributed to inaccuracies in precisely recording plant positions. Irregularities in bottom bathymetry prohibited formation of

the idealized square quadrat shown in Figure 4. During the course of a mapping dive, perimeter lines inevitably became somewhat slack due to wave surge and thus contributed a slight error in positioning of the movable meter square quadrat. Errors in estimating algae locations when mapping positions onto the recording slate (Fig. 6) were a further limitation. An indication of the magnitude in the plotting errors alluded to above can be visualized by referring to the B-2K quadrat pictorial maps. The dashed circle symbols shown are winter estimates of Macrocystis holdfasts, while the solid circles are summer estimates.

A rather serious limitation to obtaining a comprehensive mapping is apparent from an examination of Table VI. Rather than being able to collect the majority of species at one time, many species seen for the first time, were collected near the end of the survey, during the summer months (presumed to be the optimum settlement and growth period). For this reason some foliacious Rhodophyta could not be mapped explicitly as they were not sufficiently familiar to allow accurate identification and thus such plants were merely recorded as "other" non-corallines (Table B1).

Due to the size constraints imposed in counting (Fig. 5), certain species were not mapped upon each observation. This was notably true of Callophyllis spp. (height) and Peyssonelia (area). A size bias was thus imposed which appreciably underestimated the true frequency of smaller-sized species.

The primary environmental difficulties encountered in carrying out this investigation were those related to adverse wave conditions. Observed significant wave breaker heights of 1.5 meters or higher, were sufficient to preclude the possibility of attempting to reach the kelp bed by swimming from shore because of the inability to safely pass through the surf zone. If diving from a boat, similar wave conditions would lead to poor underwater visibility and interminable diver disorientation caused by wave surge.

An apparent phytoplankton bloom during a spring dive when wave conditions were calm was so intense that the resulting visibility experienced was less than an elbow's length making useful work impossible.

In addition to environmental difficulties, equipment problems, e.g., those involving damage, loss, or misplacement often necessitated altering the original purpose of a dive if not cancellation.

2. Photographic Interpretation

Pitfalls to objective time series analysis of aerial photos over water include variations in water clarity, height of tide, coastal currents, surface wind velocities, cloud cast, and ocean wave spectra. Parallax distortion at photograph edges, and type of film/filter used are equipment related factors which also contribute to interpretational errors. Altitude of aircraft, time interval between overflights and time of year of pictures taken are especially important in judging the significance of the canopy outlines drawn in Fig. 16, and Figs. D1-D6.

TABLE VI

Monthly Frequency of Species Newly Collected*

Sept.	6,(2)**	Mar.	(no dives)
Oct.	2,(3)	Apr.	0,(8)
Nov.	0,(3)	May	2,(9)
Dec.	(no dives)	June	6,(6)
Jan.	3,(7)	July	19,(15)
Feb.	7,(6)	Aug.	6,(3)

*Table indicates the month, when a species was first collected.
**Number in parentheses represents frequency of dives for that month.

3. Refraction Analysis

All digital computers are subject to finite size grid spacing and time step approximations. Since the bathymetry gradient is shallow in the Del Monte Beach study area (Fig. 17) it was hoped that errors generated in attempting to match actual continuous conditions would not be serious. Dobson (1967) has discussed the validity of wave refraction theory as it applies to his computer program simulation of known wave conditions.

B. EVALUATION OF DATA IN RELATION TO PREVIOUS RESEARCH

1. Minter (1971)

The number of different species collected during this investigation is not necessarily inconsistent with Minter's 1971 comment that the benthic algal community in the Del Monte Beach kelp bed was not diverse. Minter was

Portion of Bathymetry Grid Used In Wave Refraction Analysis

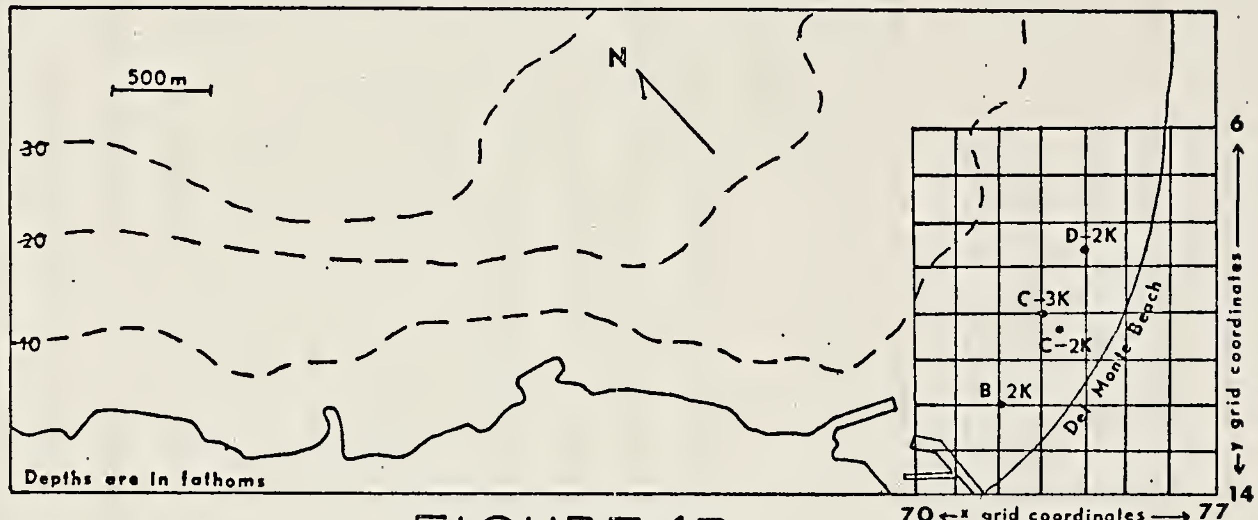


FIGURE 17

primarily interested in collecting and identifying faunal species. Also, a considerable proportion of the species found by this investigator was collected in the region between A and B transects which Minter did not survey. His comment that seventy percent of the total macroscopic plant community observed in his 9 m^2 quadrat near station C-2, (Fig. 2) was of coralline algae, does match quite well with relative frequency calculations tabulated by this investigator at C - 2K (Table I). Minter's quadrat subarea maps reveal the same trend of few species in sandy areas, and a peak in flora and faunal frequencies near shale ledge edges.

2. Davis (1974)

Davis, while studying the distribution of benthic ascidian populations in relation to the City of Monterey sewer outfall, also reported dense aggregations of organisms on shale outcroppings, with maximum densities near the edges. In addition, he documented limited circumstantial evidence that *Macrocystis* meristems of uppermost blades were suffering deleterious effects if in the near vicinity of the sewer outfall effluent. As seen in the October 1971 to January 1974 photos, the observed recession to deeper water of the kelp bed surface canopy near the observed sewer outfall surface boil, may be an indication that the meristem response described by Davis has been in evidence over a larger area and over a longer period of time than previously reported. The fact that the overall area extent of this same surface canopy has been apparently increasing while becoming established in deeper water remains to be explained.

3. Booth (1971)

By comparing the orientation of the shale edges depicted in Figs. 11-14, and the orientation of the bordering beds of *Macrocystis* canopies in Figs. D1-D4, to the shale ledge orientations shown by Booth, one can recognize a general elongated northwest/southeast trend. Though Booth's primary intent was to investigate the distribution of rock boring clams in the kelp bed area, the inclusion of ledge outlines in his maps permitted geological comparisons with the data obtained in this investigation. Dr. R. S. Andrews, Naval Postgraduate School (personal communication), confirmed the observed ledge orientation shown in Figs. 11-14, stating that it parallels the structural texture (i.e., the strikes of folds and fault planes), which have been attributed to this area.

4. Haderlie, Mellor, Minter, and Booth (1974)

Haderlie *et al*., in assessing environmental factors influencing the benthic biology off the Del Monte Beach kelp bed, measured the refracted wave energy gradient along Del Monte Beach, as estimated from aerial photographs of surf zone width. Since quadrats B-2K, C-3K, and D-2K are in about the same depth of water, one would expect that the energy gradient for these sites should compare with surf width energy estimates directly inshore. From a study of Table VII (this report), it is evident that there is close agreement with appropriate values presented in Fig. 9 of Haderlie *et al*., (1974).

TABLE VII

A Comparison of Wave Height Values Near Quadrat Sites

. (Refraction Program Written by R.S. Dodson, 1967)

Input Data:

Wave Period = 8 seconds

Deep Water Direction = 315°T

Deep Water Wave Height = 5 feet (1.58 m)

Bathymetric grid spacing = 750 feet (229 m)

Wave approach time step = 9.2 seconds

Quadrat Positions on Bathymetry Grid (see Fig. 71a)

Quadrat	X-Coord.	Y-Coord.
D-2K	74.0	8.6
C-3K	73.0	10.0
C-2K	73.5	10.4
B-2K	72.0	12.0

Wave Heights at Grid Points Near Quadrat Locations

	X-Coord.	Y-Coord.	Wave Height (feet)
(D-2K)	73.9	8.7	3.5 Feet (1.15 m)
(C-3K)	73.1	9.8	2.6 (.85)
(C-2K)	73.8	10.2	2.8 (.92)
(B-2K)	72.3	11.7	1.7 (.56)

C. SUGGESTIONS FOR FURTHER STUDY

Although the total size of the combined quadrat areas was considered sufficient to provide the desired statistical analysis of the four Macrocystis canopies surveyed (Table IV), the small number of sites analyzed combined with the fact that sites were not chosen randomly, precludes any estimation of species diversity and distribution with respect to the kelp bed as a whole. A future survey based on such techniques as those outlined by Cox (1972), could be recommended for such endeavors.

Miller and Geibel (1973) and Miller (1974) have discussed the role of the sea otter Enhydra lutreus interacting with kelp and kelp bed invertebrates — notably abalone and sea urchins. The results of their intensive literature search has shown, however, no empirically documented case of Macrocystis enhancement resulting from urchin removal by sea otters, though the predation by sea urchins on Macrocystis is well documented (North, 1971). Miller (personal communication) has noted that the Del Monte Beach kelp bed region is often used as a sea otter pup nursing territory. In the same area, Minter (1971) indicated a general dearth of sea urchins, and this investigator only sighted two (underneath an overhanging shale ledge) in all dives recorded. Whether presence of sea otters is sufficient to ultimately account for such quantum jumps in canopy extent as that which apparently occurred between October 1971 and December 1972 (Figs. D2 and D3) remains unclear. Perhaps a concurrent

historical analysis of water temperatures and winter storm wave height data of this area could provide a more complete explanation.

A detailed survey of superficial substrates would surely have allowed recognition of more subtle attachment preferences than those analyzed. For example, qualitatively it was found that the non-crustose Rhodophyta could be observed more frequently on rough, pock-marked shale regions than on relatively smooth outcroppings. Additionally, this same floral group was noticed capable of growth on a variety of detrital deposits – particularly _Rhodymenia_ _spp_. It is often assumed that the giant kelps attach only to rocky, firm substrates, however, Thompson (1959) has observed _Macrocystis_ _pyrifera_ holdfasts sustaining growing plants while attached in soft substrate (laden with deep deposits of silt and sand) near Santa Barbara (Fig. 1). Although no such described plants were detected in the Del Monte Beach region by this investigator, there were holdfasts found attached to annelid tube worm mounds, to clam shells, clam siphons, pebble sized rocks, plastic bags, and even to a yellow garden hose buoy which marked quadrat C-2K. The adaptability of this plant to tolerate such a wide range of substrates may be one reason why it has virtually excluded _Nereocystis_ from the studied area. In any case, studying the variable settling preference of algae spores is a topic which deserves more detailed attention.

While investigating the concept of algal succession within a _Macrocystis_ _p_. kelp bed in Southern California,

Foster (1974) included competition for available space, presence of a kelp canopy overstory, and faunal predation as among the forces at work, shaping the eventual destiny of the benthic algal community. The fact that this investigation revealed *Macrocystis* Near Field Holdfast Areas (see Results of the Investigation, Four Substrate Types) to contain more frequent clusters of crustose corallines and a similar number of articulated corallines compared to total area surveyed densities while they contained below expected values of non-coralline Rhodophyta and understory Phaeophyta (Table IV), might be understood by recalling the diverse infauna of the *Macrocystis* holdfast and that fleshy algae could be a more palatable food for any such foragers prone to wander beyond the confines of the holdfast haptera network. Another possible explanation might be that the aggregation of sporophylls overlying the holdfasts of some plants might preferentially sweep away other than coralline algal spores. In any case, biologic interactions such as competition, grazing, etc., and especially those of epibiotic associations, as they affect plant diversity, distribution and stability, should also be given consideration in any future related research.

IV. SUMMARY

1. As part of a subtidal SCUBA study of benthic flora in the Del Monte kelp beds, there were approximately fifty species of algae and one species of eel grass collected and identified.

2. Of the collected plants, the thirteen most abundant and/or easily recognized genera were symbolically mapped where occurring (if they exceeded specified size criteria) within four, 12 meter square quadrats. (Additionally, unidentified non-coralline algae were mapped under the category, "other" species).

3. The thirteen identified genera and the one unidentified species category were combined into five floral groups according to a taxonomic/height classification system adopted from Neushal (North, 1971).

4. Within the mapped quadrats, the abundance of each genera group was found to be significantly less in defined Large Scale (greater than 16 m^2) Sand Covered Shale Areas, significantly greater near defined shale Ledge Edge Areas, and dependent on genera grouping when within so-called Macrocystis Holdfast Near Field Areas.

5. Based on observations of Macrocystis plants at one quadrat site, the mean number of stipes counted per holdfast was found to decrease in the time interval between winter and following summer investigation periods. In addition, based on a blind-cast type sampling of Macrocystis, it was

again noted that the mean number of stipes per holdfast was greater in winter than in summer. However, different causes for the apparent stipe number declines were suspected.

6. The kelp canopy, as revealed by five aerial photographs spanning a five year interval, was particularly characterized by a substantial size increase between October 1971 and December 1972. The kelp beds in the vicinity of the City of Monterey sewer outfall were observed to be apparently receding into deeper water over the period from October 1971 until January 1974.

7. Theoretical wave refraction energy computations were perceived to be consistent with finding *Zostera* (and noting best developed *Cystoseira* and *Dictyoneuropsis*) in predicted calm water areas, as well as finding *Nereocystis* and *Pterygophora* in predicted relatively high wave energy areas.

APPENDIX A

TABLE A

SPECIES LIST OF SPECIMENS COLLECTED WITHIN THE DEL MONTE BEACH KELP BED (September 1973 to August 1974)

(For explanation of Species List format, see RESULTS OF THE INVESTIGATION, Species List)

1. Agardiella tenera (p. 693, pl. 62)†
   Rare; B-2K††; Shale covered by sand
   Thallus filamentous, slender, cylindrical, with widely spaced lateral branches; up to 20 cm in length; dark red.

2. Ahnfeltia sp (p. 271, pl. 64)
   Scarce; D-2K; Shale
   Thallus filamentous, terete; up to 20 cm in length; dark red.

3. Anisocladella pacifica (p. 343, pl. 188)
   Scarce; C-2K; Shale
   Thallus foliaceous, veins, project beyond blade; up to 4 cm in length; pale red.

4. Antithamnion sp. (p. 306)
   Scarce; C-2K; Bosiella, detrital Nereocystis stipe.
   Thallus filamentous, branching opposite; up to 10 cm in length; dark purple.

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†Where applicable, page and plate number citations refer to Smith (1969).

††Abbreviations for quadrat locations either refer to a quadrat, e.g., B-2K, or to a location in the vicinity of a transect line of bearing, e.g., C. The abbreviation A/B signifies the species was collected between A and B transects. The abbreviation S.O. signifies the species was found near the City of Monterey sewer outfall.

5. Bosiella orbigniana (p. 637, pl. 51)
Abundant; B-2K to S.O.; Shale
Thallus coralline, articulated, dichotomous branching, intergenicula cuneate to cordate; fruiting bodies generally not marginal; up to 25 cm in length; pink to lavender in color.

6. Branchioglossum woodii (p. 335, pl. 86)
Scarce; A/B and B-2K; Tubes of sedentary annelids
Thallus foliaceous; fruiting bodies situated in two parallel, linear, interrupted sori on either side of secondary blade midribs; up to 5 cm in length; pale red in color.

7. Callophyllis flabellulata (p. 686)
Common; A/B to D; Shale, Tubes of sedentary annelids clam siphons, detritus;
Thallus foliaceous, main axis up to 5 times as broad as subsequent branches; up to 10 cm in length; medium red.

8. Callophyllis heanophylla (p. 690, fig. 34)
Scarce; B-2K; Shale
Thallus foliaceous; fruiting bodies distributed irregularly in upper branches, bulging on both sides of the thallus; up to 10 cm in length; medium red.

9. *Callophyllis pinnata (p. 251, pl. 58)
Rare; C; Shale
Thallus foliaceous, ultimate segments relatively long and with convexly acute tips; up to 15 cm in length; dark red.

10. Callophyllis thompsonii (p. 689, fig. 33)
Scarce; D-2K; Shale
Thallus foliaceous, broad penultimate segments; up to 6 cm in length; medium red.

11. Coilodesme californica (p. 131, pl. 19)
Scarce; A/B; Cystoseira
Thallus obovate, sac shaped; up to 15 cm in length; light brown.

12. Corallina officinalis (p. 229)
Abundant; A/B to S.O.; Shale
Thallus coralline, articulated; main axis intergenicula subcylindrical, branching pinnate; up to 15 cm in length; dark pink to lavender.

13. Cystoseira osmundacea (p. 156, pl. 34)
Common; A to D; Shale
Lower branches foliaceous, upper branches cylindrical and with small vesicles; up to 2 m in length; dark brown lower branches, medium brown upper branches.

14. Desmarestia herbacea (p. 121, pl. 17)
Scarce; A/B; Detritus, Shale
Thallus ribbon like, branching opposite, and proliferous; up to 10 cm in length; yellow brown.

15. Desmarestia latifrons (p. 120, p. 18)
Scarce; D; Shale covered by sand
Thallus linear, branching alternate, with a small percurrent midrib; up to 1 m in length; dark brown.

16. *Desmarestia munda (p. 121, pl. 17)
Common; A/B and D; Shale covered by sand
Thallus ribbon like, branching opposite, with opposite pairs of aculei along margins; up to 3 m in length; medium to dark brown.

17. Dictyoneuropsis reticulata (p. 140, pl. 23)
Very abundant; A/B to S.O.; Shale
Blades strap-like, with reticulated pattern except on midrib; up to 2 m in length; medium to dark brown.

18. Enteromorpha intestinalis (p. 49, pl. 5)
Scarce; A/B; Tubes of sedentary annelids
Thallus narrowly cylindrical; up to 10 cm in length; pale green.

19. Enteromorpha linza (p. 44, pl. 3)
Scarce; A/B; Tubes of sedentary annelids
Thallus foliaceous, lanceolate, semi rigid, blade margin contorted; up to 20 cm in length; bright, medium green.

20. *Fauchea sp. (p. 703)
Rare; C; Shale, masking crabs
Thallus foliaceous, similar in outline to Callophyllis flabellulata but irridescent; fruiting bodies on the blade margins; up to 10 cm in length; medium red.

21. *Fryeella gardneri (p. 707, fig. 41)
Rare; C; Shale
Thallus foliaceous, widest blades formed at second or third order of branching; fruiting bodies in irregular graphiform sori with sori separated by narrow bands; up to 10 cm in length; dark red.

22. Griffithsia pacifica (p. 324, pl. 83)
Scarce; D-2K, C-2K and C-3K; Shale
Thallus filamentous, branching dichotomous; up to 5 cm in length; pale red.

23. *Hallymenia schizymedoides (p. 680, fig. 30)
Rare; A/B; Tubes of sedentary annelids
Thallus foliaceous, blade lanceolate with a short stipe, surface of blade with fine leather texture; up to 10 cm in length; dark red.

24. Heterosiphonia japonica (p. 722, fig. 50)
Scarce; C-2K, D-2K; Shale
Thallus bushy, main axis cylindrical, branching alternate; up to 6 cm in length; medium red.

25. Laurencia spectabilis (p. 377, pl. 97)
Common; B-2K and C-3K; Shale
Thallus foliaceous, branching pinnate, tips of branchlets oblong to obovate; up to 15 cm in length; medium to dark red.

26. Lithodura sp.
Scarce; D-2K; Shale
Thallus crustose, somewhat rough in texture; dark purplish-brown.

27. Macrocystis integrifolia (p. 143, pl. 26)
Rare; C-3K; Shale
Thallus similar to M. pyrifera although blades somewhat narrower, holdfast more tabular in outline, and rhizomes more flattened with haptera branching from lateral margins; length at least 14 m; medium brown.

28. Macrocystis pyrifera (p. 144, pl. 33)
Very abundant; A/B to S.O.; Shale, tubes of sedentary annelids, clam siphons
Holdfast more conical, haptera arise from all sides at base of primary stipe, rhizomes more cylindrical; length at least 14 m; medium brown.

29. Nereocystis luetkeana (p. 141, pl. 24)
Rare; S.O.; Shale
Thallus with a single cylindrical stipe gradually increasing in diameter to form a bulb at the distal end; up to 12 m in length; medium to dark brown, blades paler than stipe.

30. Peyssonelia profunda (p. 668)
Abundant; A/B to D; Shale, granite cobbles
Thallus crustose, smooth texture; dark reddish-brown.

31. Phycodrys isabelli
Rare; B-2K; Tubes of sedentary annelids
Thallus foliaceous, secondary blades obovate, distinct alternate branching veins; up to 5 cm in length; medium red.

32. Phycodrys profunda
Scarce; B-2K; Shale
Thallus foliaceous, blades elliptical to obovate, distinct opposite branching veins; up to 5 cm in length; medium to dark red.

33. Phycodrys setchelli (p. 342, pls 87,88)
Common; B-2K, C-2K, C-3K, D-2K; Shale, tubes of sedentary annelids
Thallus foliaceous, blades distinctly obovate, veins with opposite branching; up to 3 cm in length; pale to medium red.

34. Pikea sp. (p. 201)
Common; B-2K, C-2K, C-3K, D-2K; Shale
Thallus foliaceous, narrow, pinnately branched, blade tips sharply pointed; up to 4 cm in length; medium to dark red.

35. Pleonosporium vancouverium (p. 321, pl. 82)
Common; B to D; Cryptochiton, tubes of sedentary annelids
Thallus filamentous, plumose; fruiting bodies on branches borne alternately, the lowermost always on the abaxial side; up to 2 cm in length; medium red.

36. Plocamium pacificum (p. 264, pl. 62)
Common; A/B to D; Shale, tubes of sedentary annelids
Thallus foliaceous, narrow, branches subcylindrical, branching sympodial, ultimate branchlets unilateral; up to 25 cm in length; medium red.

37. Polyneura latissima (p. 341, pl. 87)
Common; A/B to D; Shale, clam siphons
Thallus foliaceous, distinct anastomosing veins, distal end of blade usually lacerate; up to 10 cm in length; medium red.

38. Polysiphonia brodiaei (p. 361, pl. 93)
Rare; A/B; Detrital blade of Phyllospadix
Thallus filamentous, profuse branching; up to 10 cm in length; dark red.

39. Prionitis sp. (p. 243)
Rare; A/B; Tubes of sedentary annelids
Thallus foliaceous, branches narrow but relatively thick, up to 10 cm in length; medium to dark red.

40. Pseudolithophylum neofarlowii
Abundant; A/B to S.O.; Shale, clam shells, limpet shells
Thallus crustose, surface smooth, waxy; pink to pale purple.

41. Pterosiphonia dendroidea (p. 366, pl. 95)
Common; B-2K, C-3K, D-2K; Tubes of sedentary annelids
Thallus filamentous, branching pinnate, axis and branches regularly with two segments between successive branches; up to 3 cm in length; dark red.

42. Pterygophora californica (p. 148, pl. 29)
Scarce; D; Shale
Thallus with one longitudinally arranged primary blade, with smaller pinnately arranged blades branching laterally from the stipe; up to 1.5 m in length; stipe dark brown, blades pale brown.

43. Pugetia fragilissima (p. 692, fig. 35)
Rare; A/B; information not recorded
Thallus foliaceous, membranous, blade nearly circular in outline, ruffled margins; up to 10 cm in length; medium red.

44. Punctaria occidentalis (p. 124, pl. 19)
Rare; A/B; Tubes of sedentary annelids
Thallus foliaceous, linear blade, with ruffled margins; up to 20 cm in length; light brown.

45. Rhodophysema elegans (p. 665, figs. 18,19)
Rare; B-2K; Interior of a small transparent bottle
Thallus crustose; filamentous rhizoids visible at edges; brilliant medium red.

46. Rhodoptilum densum (p. 721)
Common; B-2K, C-2K, D-2K; Shale
Thallus filamentous, large number of false branches, branches terete in form; up to 5 cm in length; medium red.

47. Rhodymenia californica (p. 300, pl. 74)
Common; C-3K; Tubes of sedentary annelids
Thallus foliaceous, narrow branches with rounded to pointed tips; up to 8 cm in length; medium to dark red.

48. Rhodymenia pacifica (p. 301, pl. 76)
Very abudant; A/B to S.O.; Shale, detritus, tubes of sedentary annelids, masking crabs
Thallus foliaceous and branches generally wider than R. californica; up to 10 cm in length; medium to dark red.

49. *Schizymenia pacifica (p. 258, pl. 61)
Rare; C; Shale
Thallus foliaceous, blade soft and slimy in texture, blade margins deeply lacinate; up to 50 cm in length; medium red.

50. Stenogramme interrupta (p. 276)
Scarce; A/B and B-2K; Shale
Thallus foliaceous, blade ligulate with broadly rounded tip; fruiting bodies irregularly dispersed near proximal end; up to 6 cm in length; medium to dark red.

51. Ulva sp. (p. 43-48)
Scarce; A/B and S.O.; Shale, Tubes of sedentary annelids
Thallus expansive, membranous, margins crenulated; up to 40 cm in diameter; medium to dark green.

52. *Zostera marina
Rare; A/B; Sand
Thallus of slender, linear shoots; up to 2 m in length including root; dark green.

53. Unidentified species #1
Common; B-2K, C-2K, D-2K; Bosiella epiphyte
Crustose; observed as dark red blotches on parent plant.

54. *Unidentified species #2
Rare; C; Dictyoneuropsis endophyte
Observed as brillant red patehes within distal end of parent blade; generally less than 1 cm in diameter.

55. Unidentified species #3
Common; B-2K; Tubes of sedentary annelids
Thallus filamentous, rigid, terete, multiple branched at distal end; up to 8 cm in length; dark red.

APPENDIX B

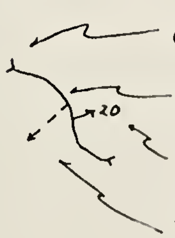
TABLE B

Mapping Symbols for Quadrat Pictorial Subarea Maps

Algae

Bo	_Bosiella_
Cao	_Callophyllis_
Coro	_Corallina_
Cyo	_Cystoseira_
Deo	_Desmarestia_
Dio	_Dictyoneuropsis_
Lao	_Laurencia_
M	_Macrocystis_ holdfast without stipes attached
otho	Other Rhodophyta than those specifically noted
Po	_Peyssonelia_
Pto	_Pterygophora_
Plo	_Plocamium_
Pho	_Pseudolithophylum_
Ro	_Rhodymenia_
12	_Macrocystis_ (in this case, with 12 stipes and idealized circular shape of measured circumference shown)
	Indicates horizontal extent greater than 150 cm^2. Also referred to as "large area."

Terrain Symbols



end of ledge

ledge edge

20 cm from ledge edge to substrate below

ledge edge overhangs substrate below for 15 cm

 large rock

P/c Area of pebbles and/or cobbles

S/S Area of sand or sand and shell coverage

Faunal Symbols

D.O. Area of *Diopatra ornata* tubes

 Abalone shell

Reference Diagram
for
Quadrat Pictorial Subarea Maps

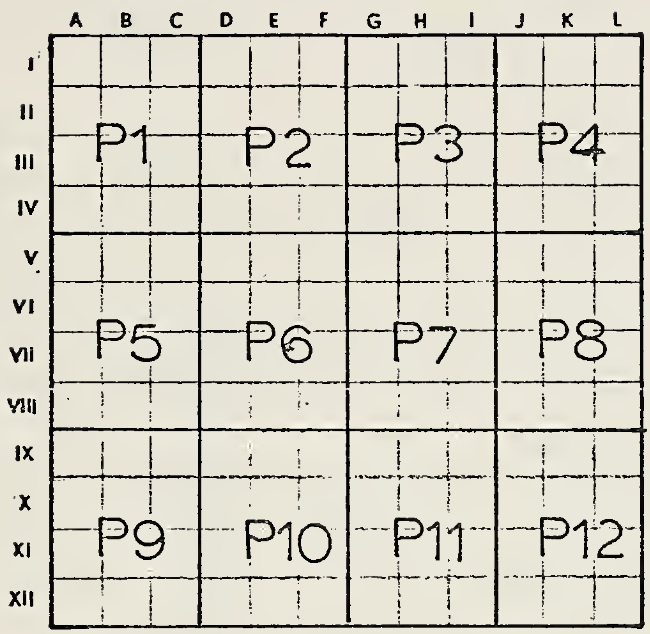
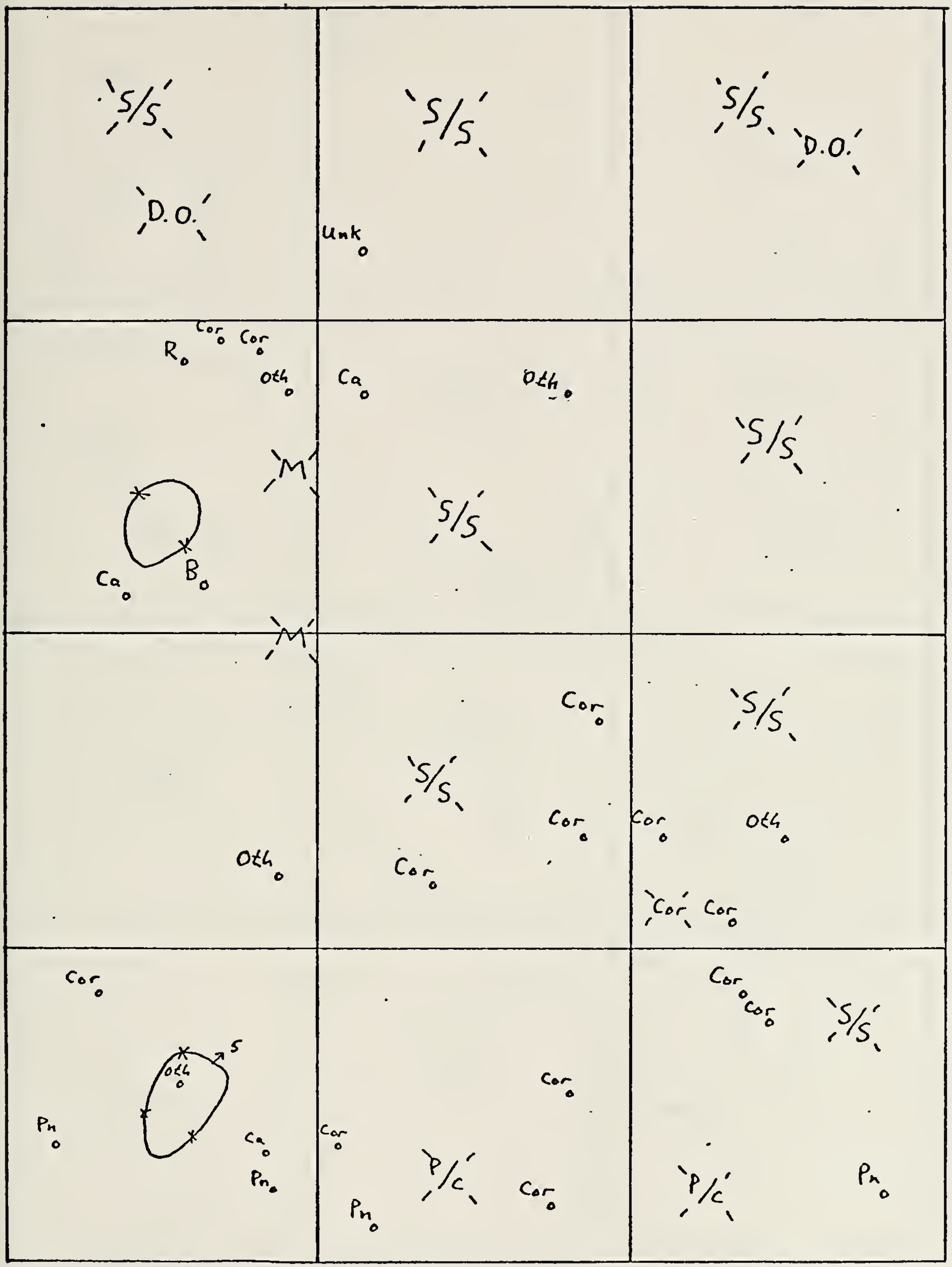
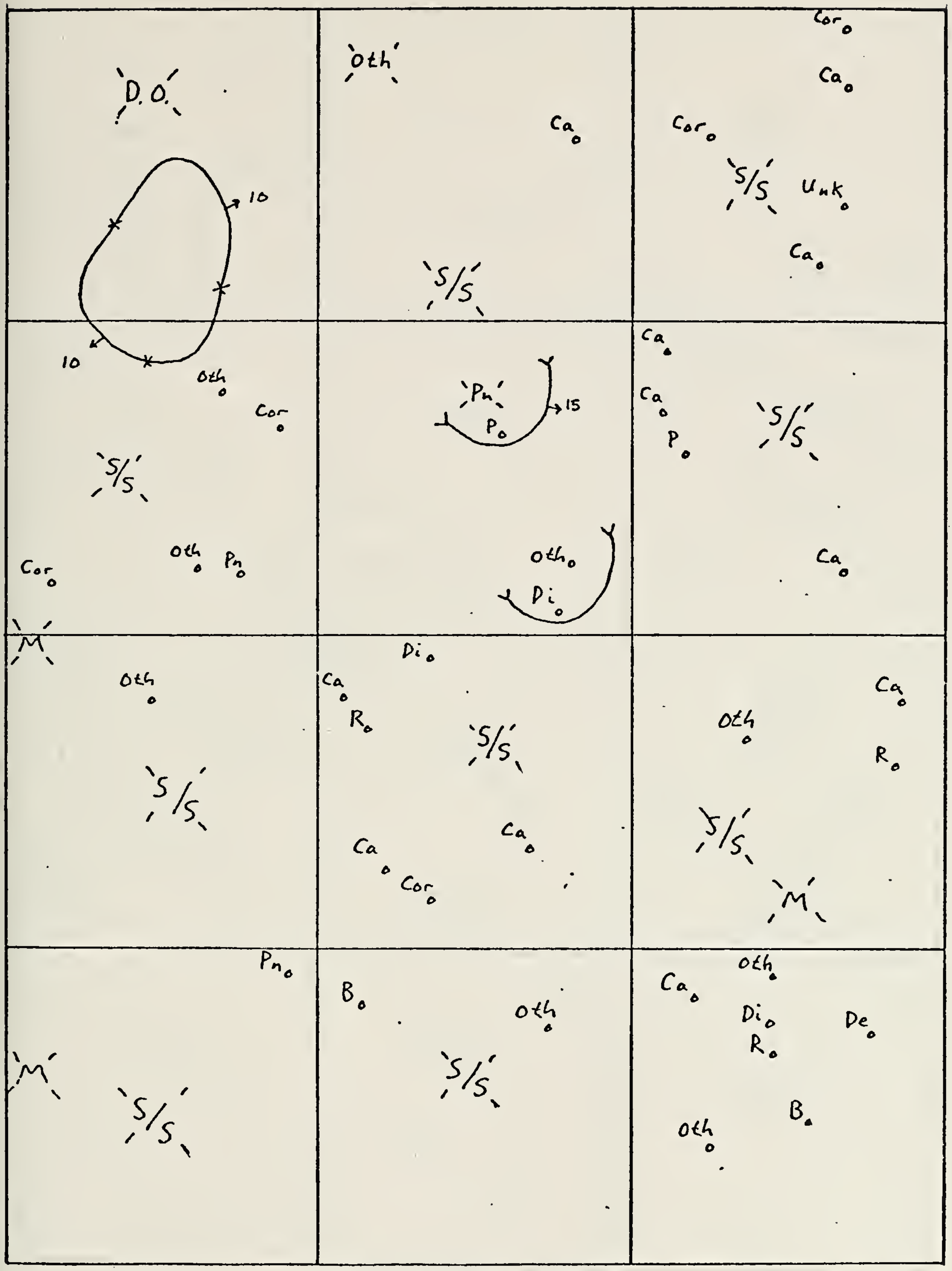


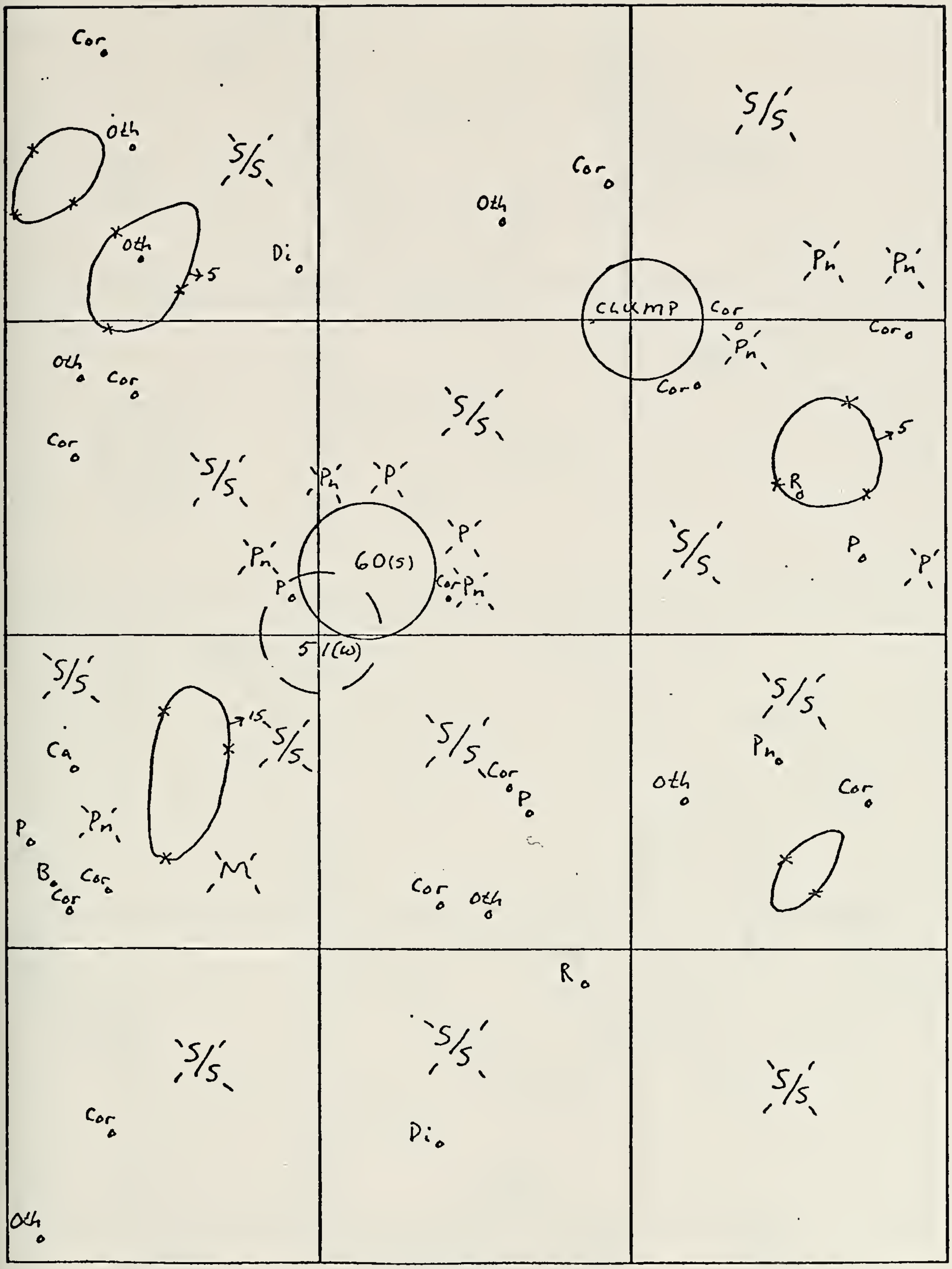
FIGURE B1



B-2K FIGURE B2 P-2



B-2K FIGURE B3 P-3



B-2K FIGURE B4 P-4

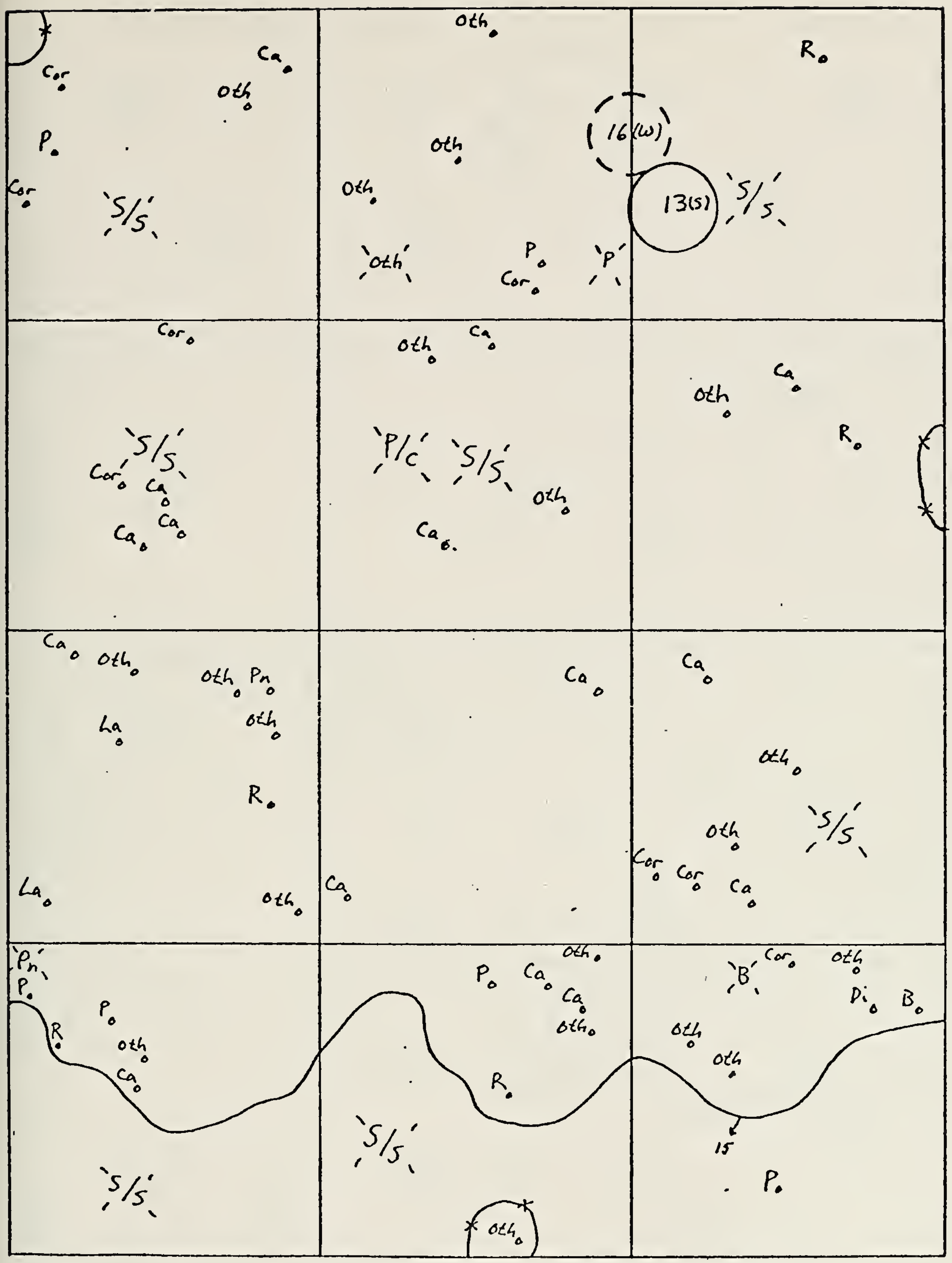
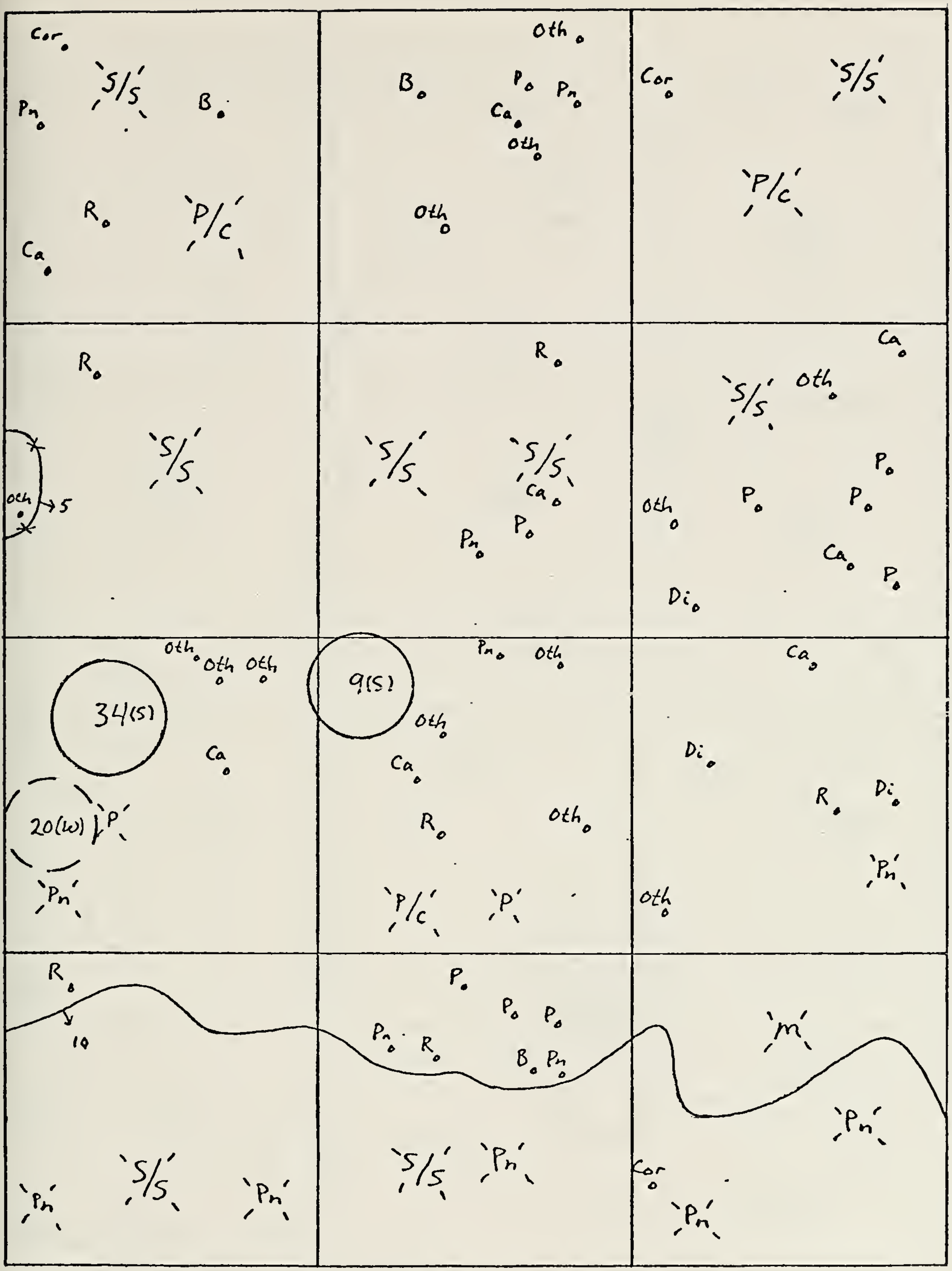
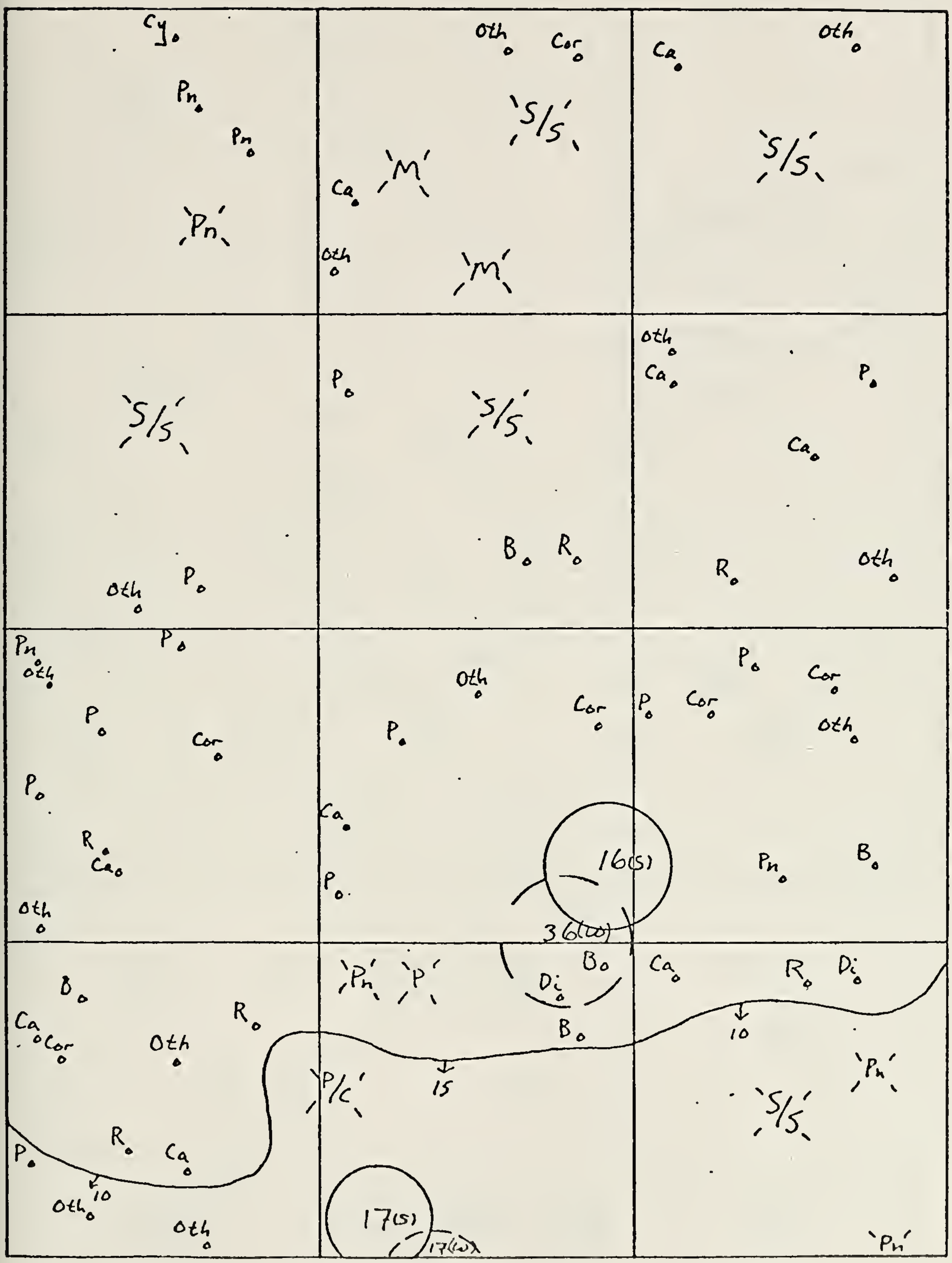


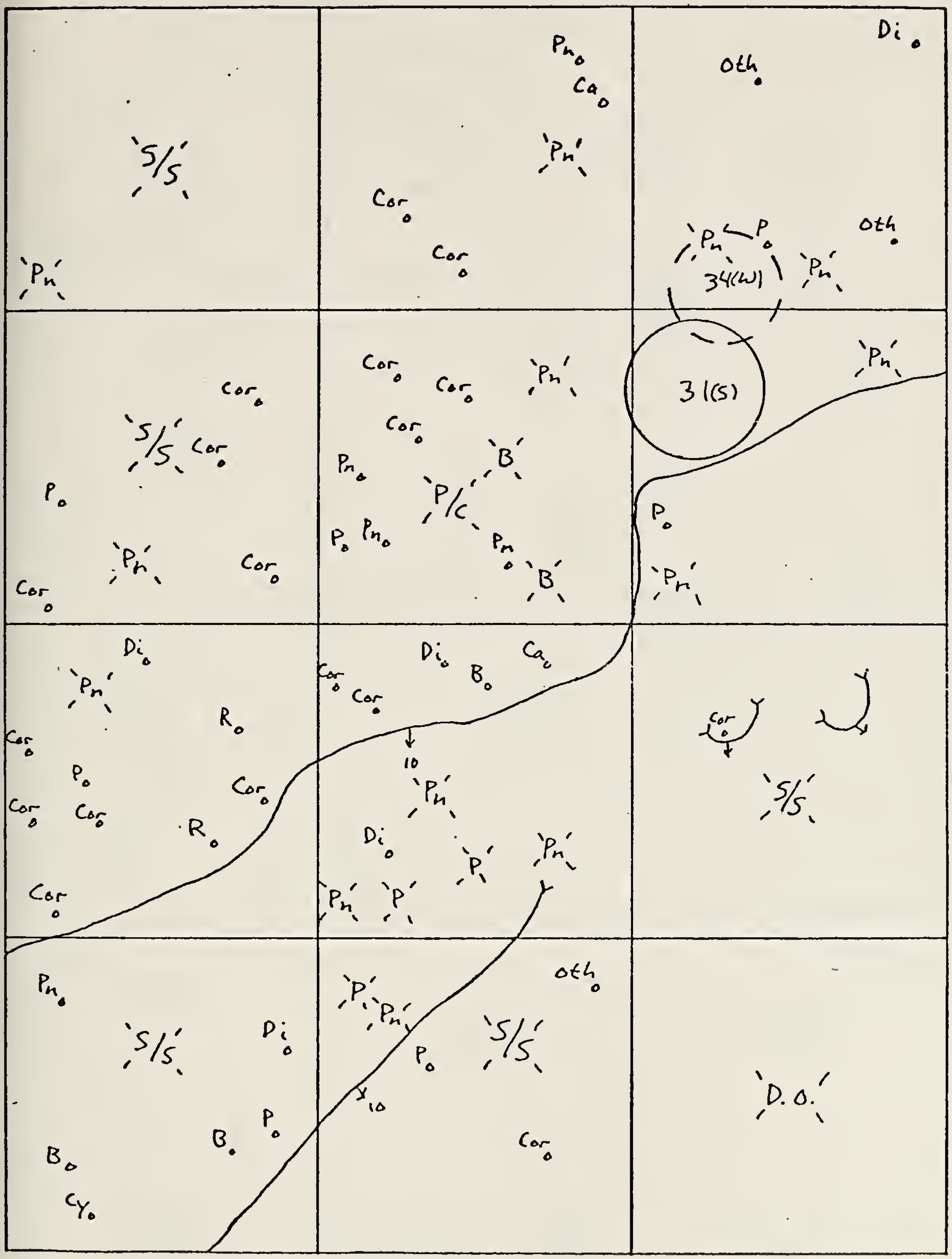
FIGURE B5



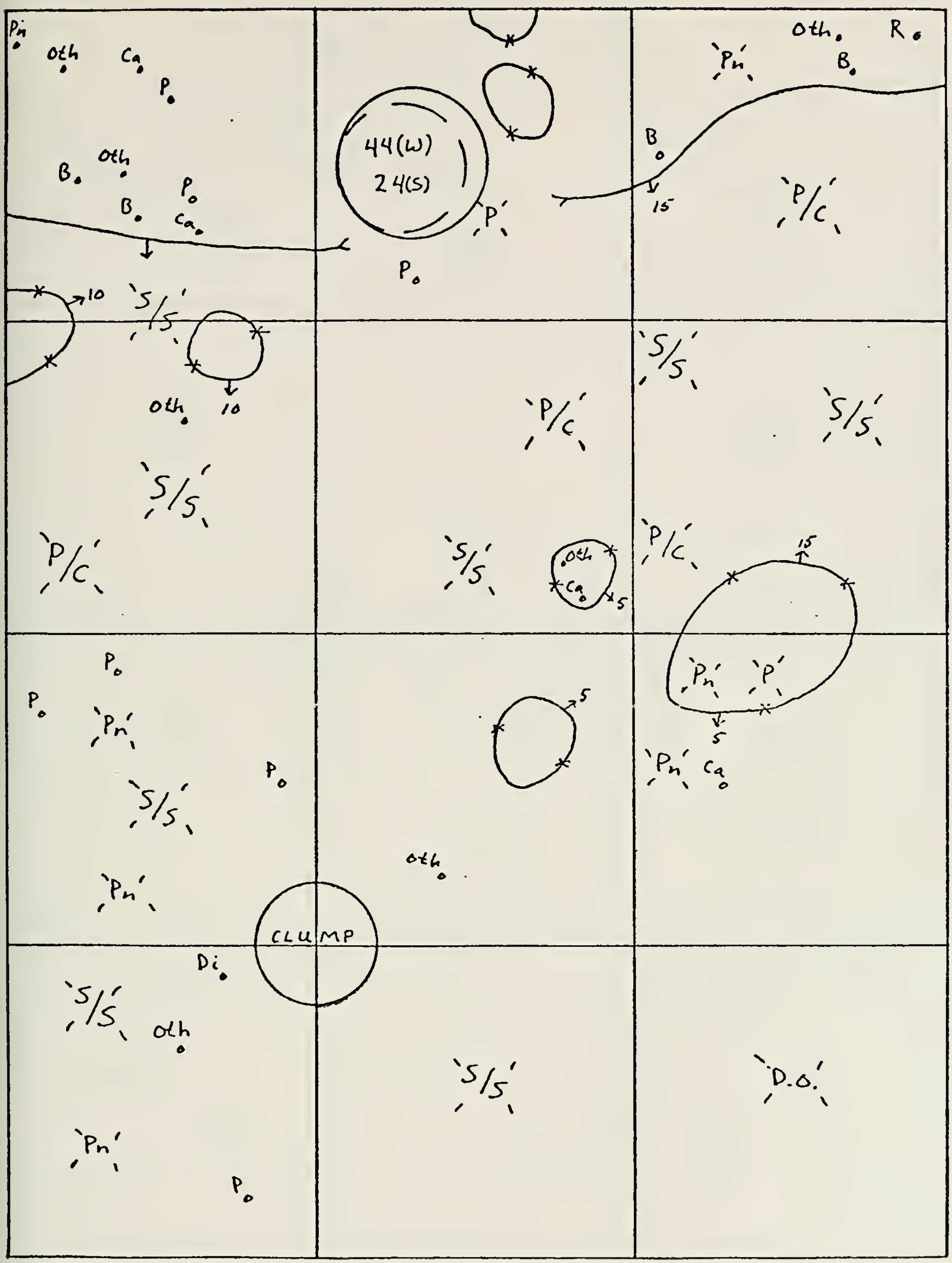
B-2K FIGURE B6 P-6



B-2K FIGURE B7 P-7



B-2K FIGURE B8 P-8



B-2K FIGURE B9 P-9

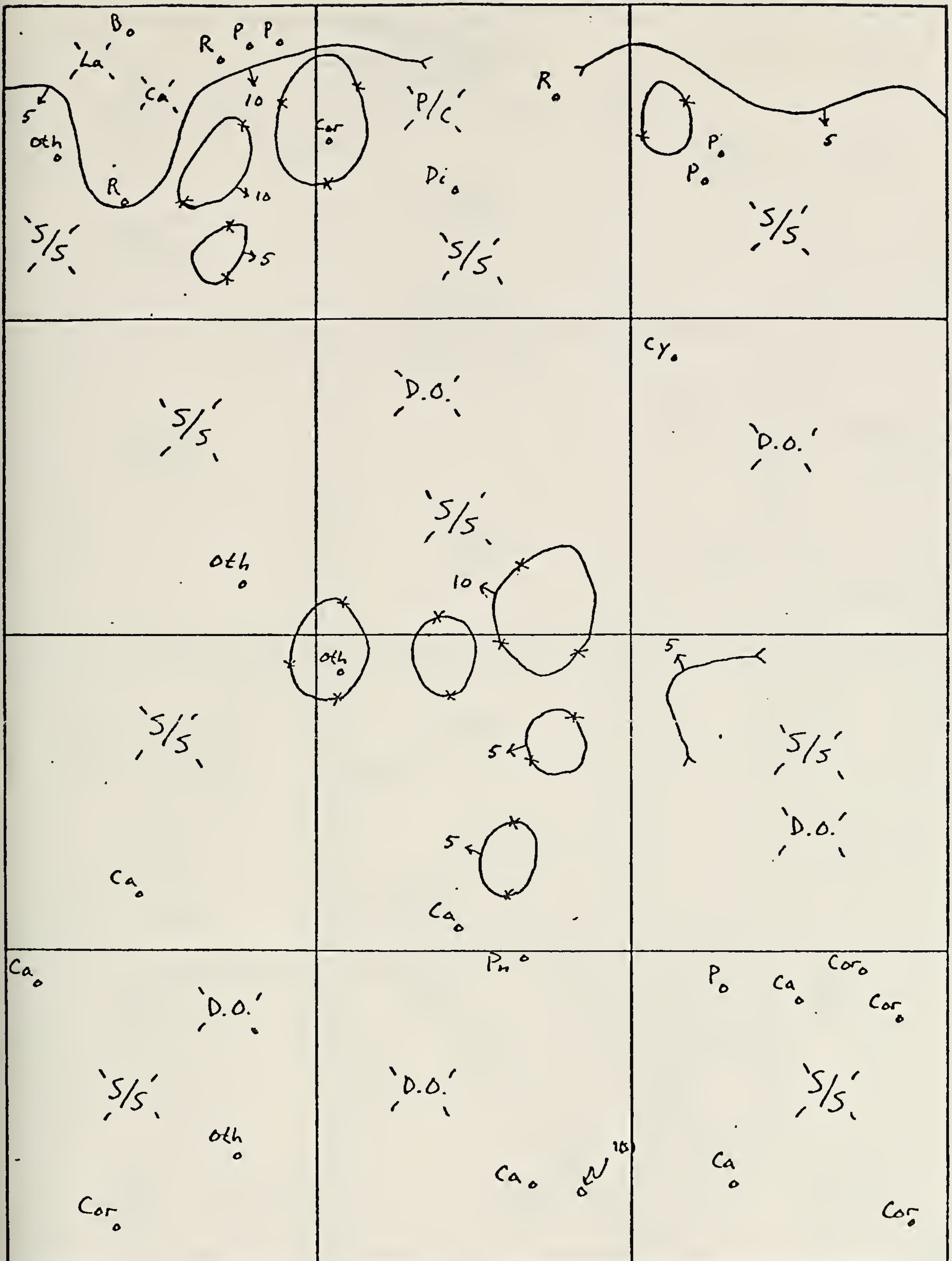
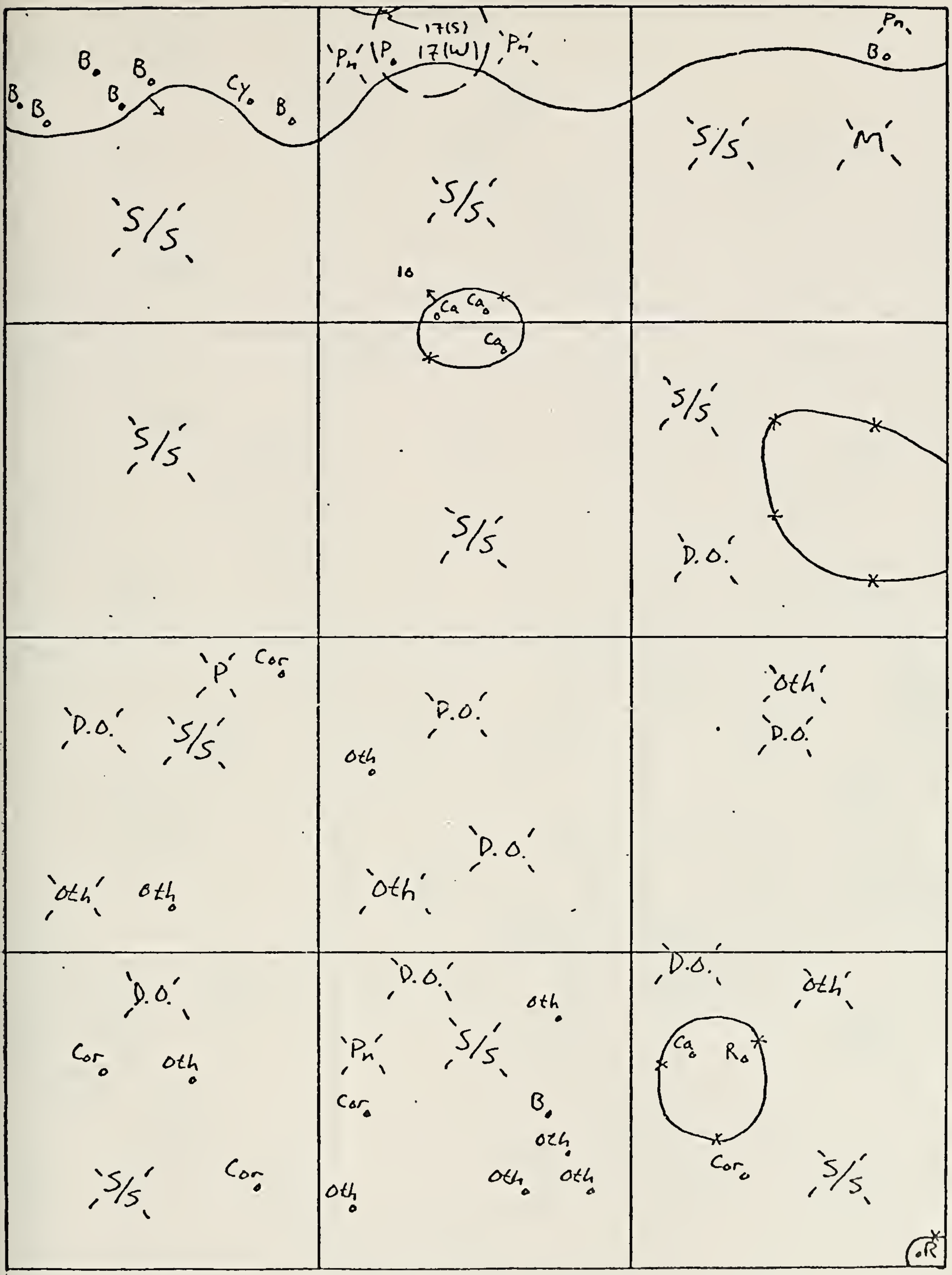


FIGURE B10



B-2K FIGURE B11 P-11

B-2K FIGURE B12 P-12

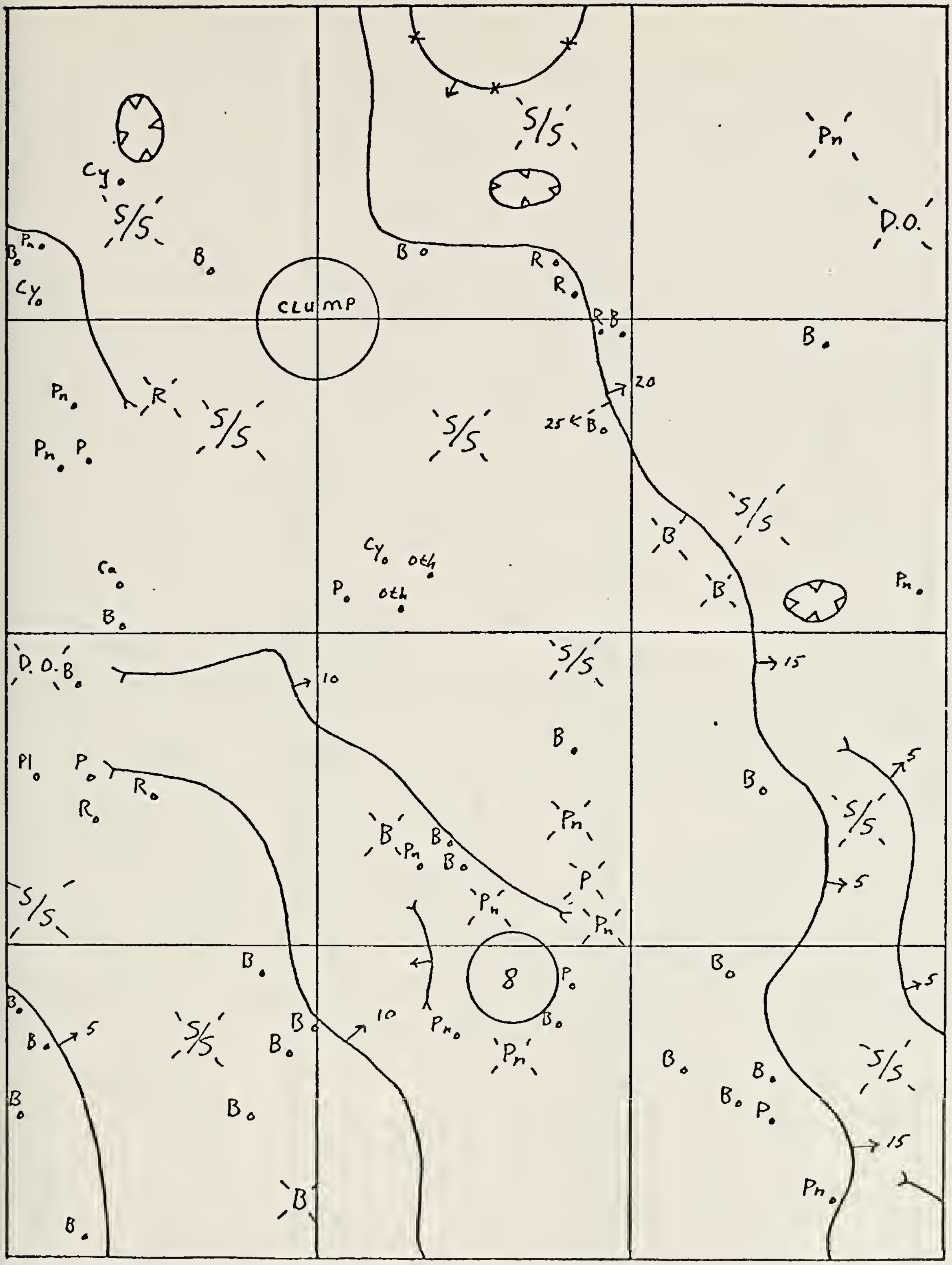
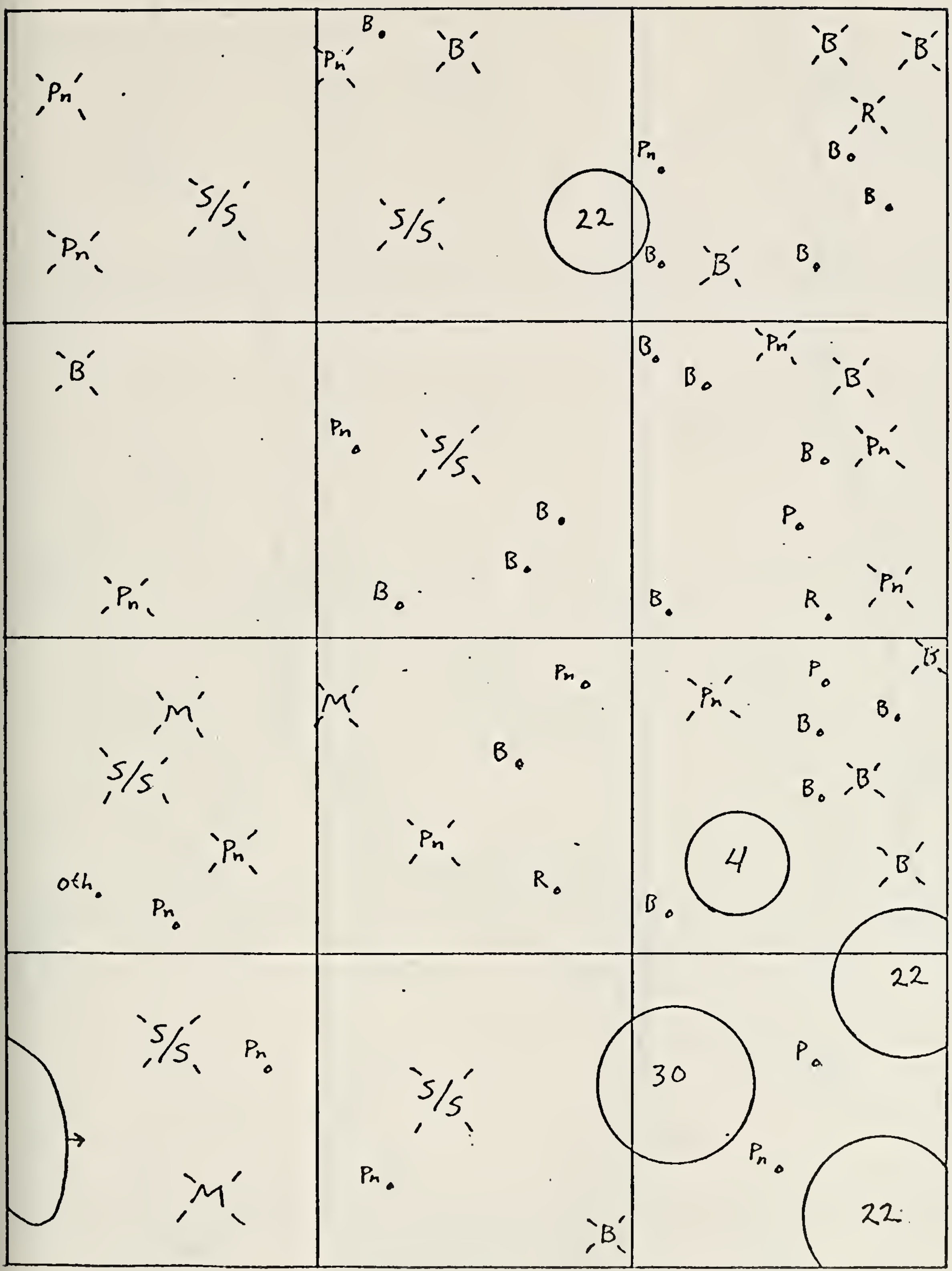
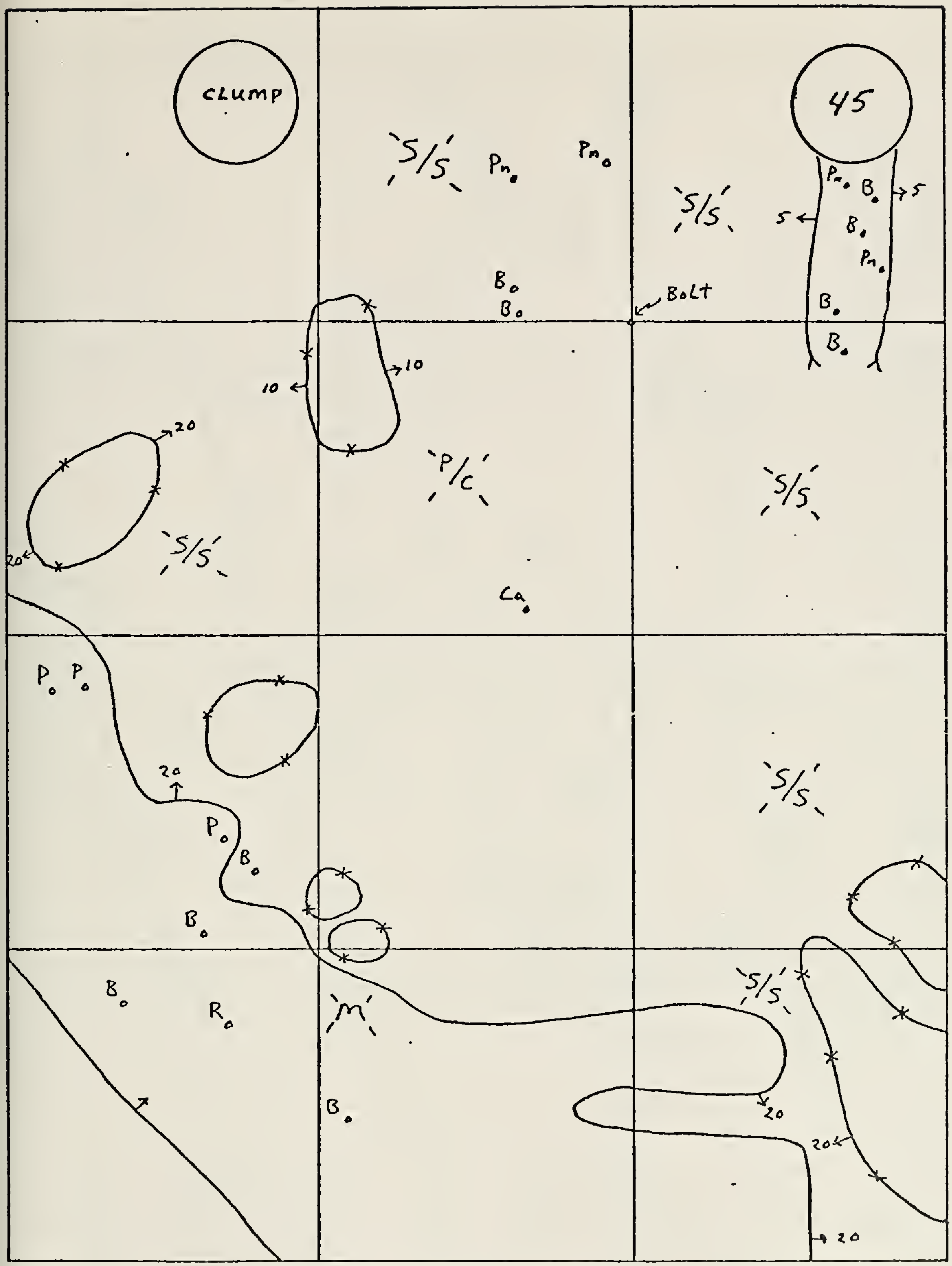


FIGURE B13

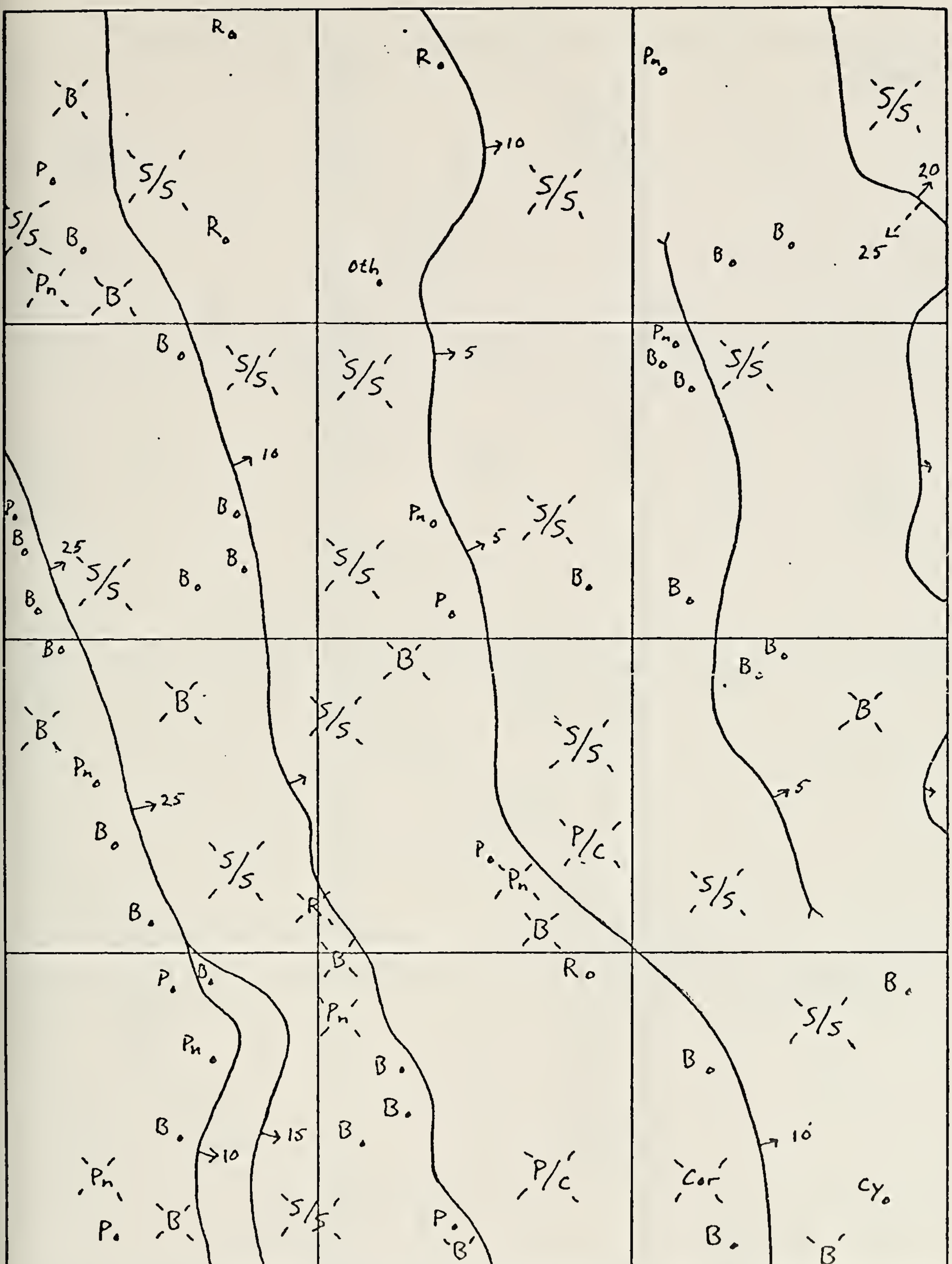


C-2K FIGURE B14 P-2

FIGURE B15

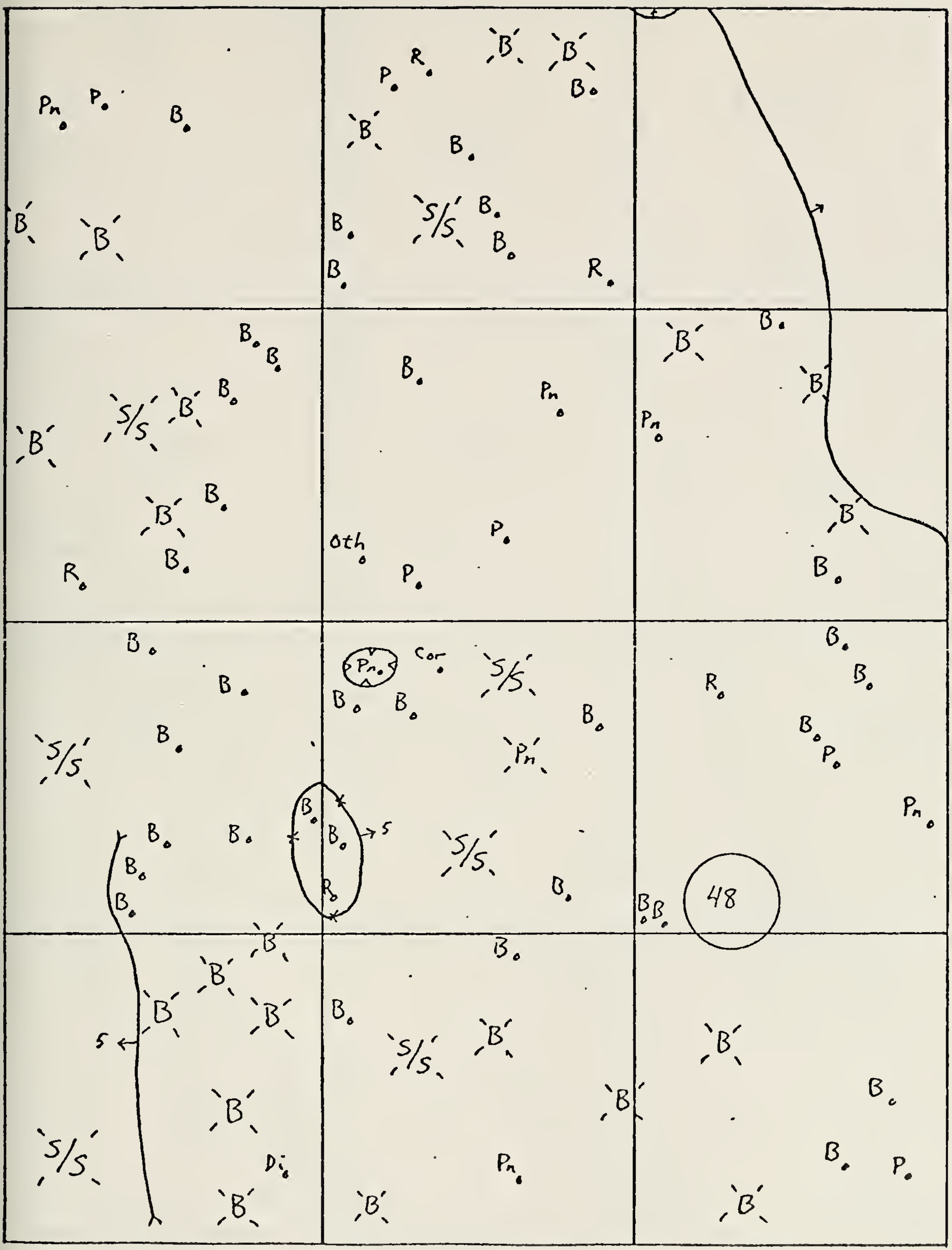


C-2K FIGURE B16 P-4

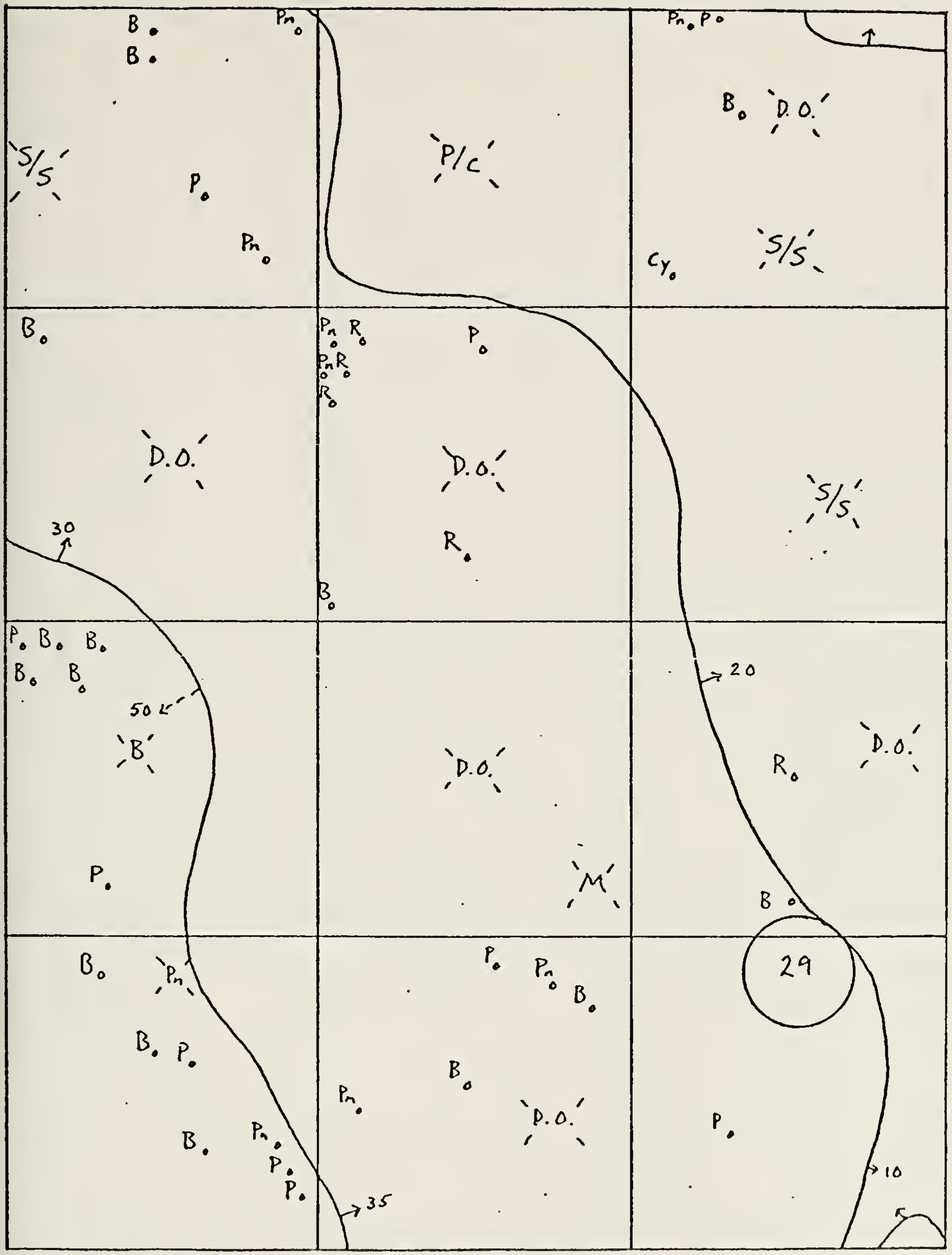


C-2K FIGURE B17 P-5

C-2K FIGURE B18 P-6



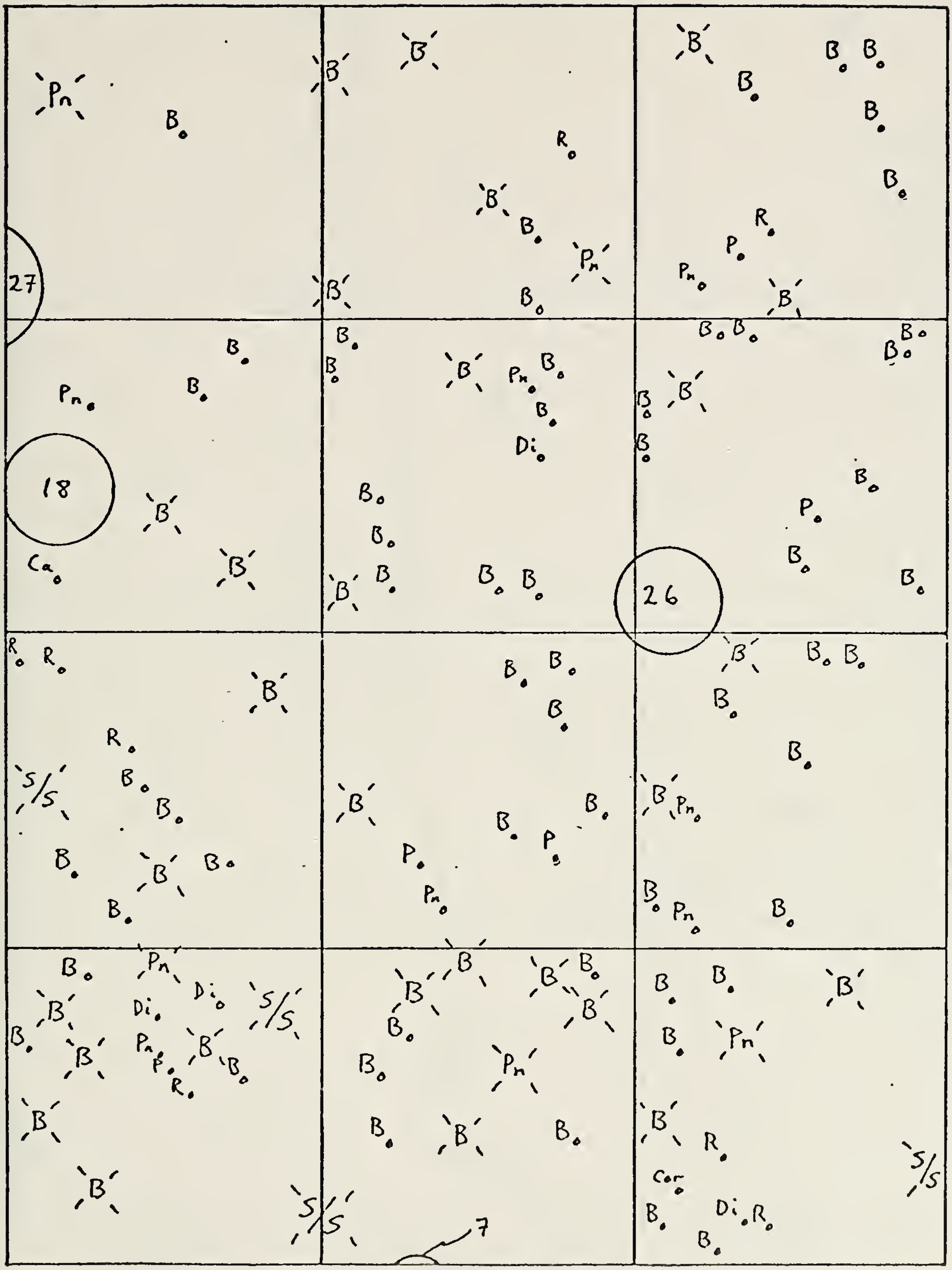
C-2K FIGURE B19 P-7



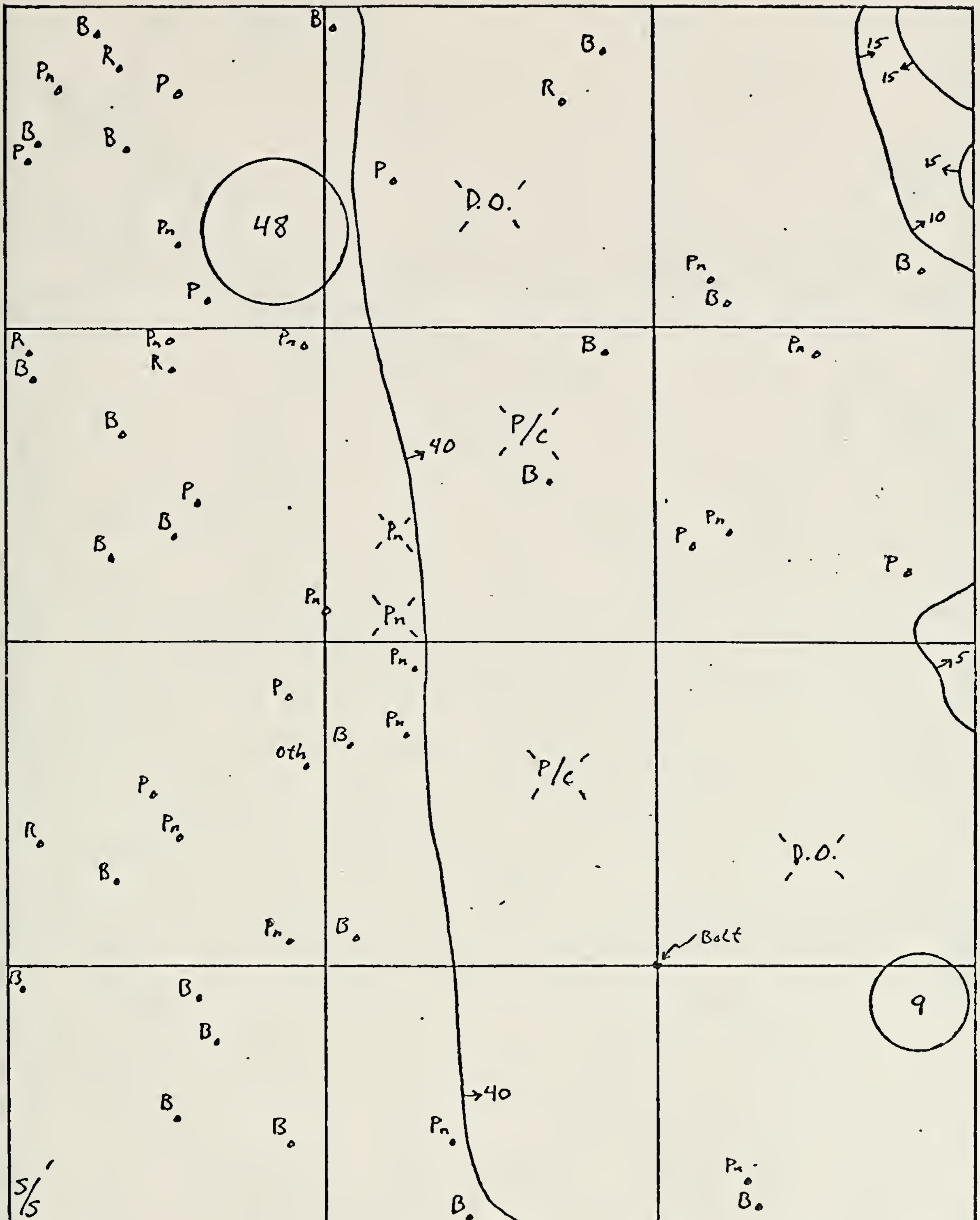
C-2K FIGURE B20 P-8

C-2K FIGURE B21 P-9

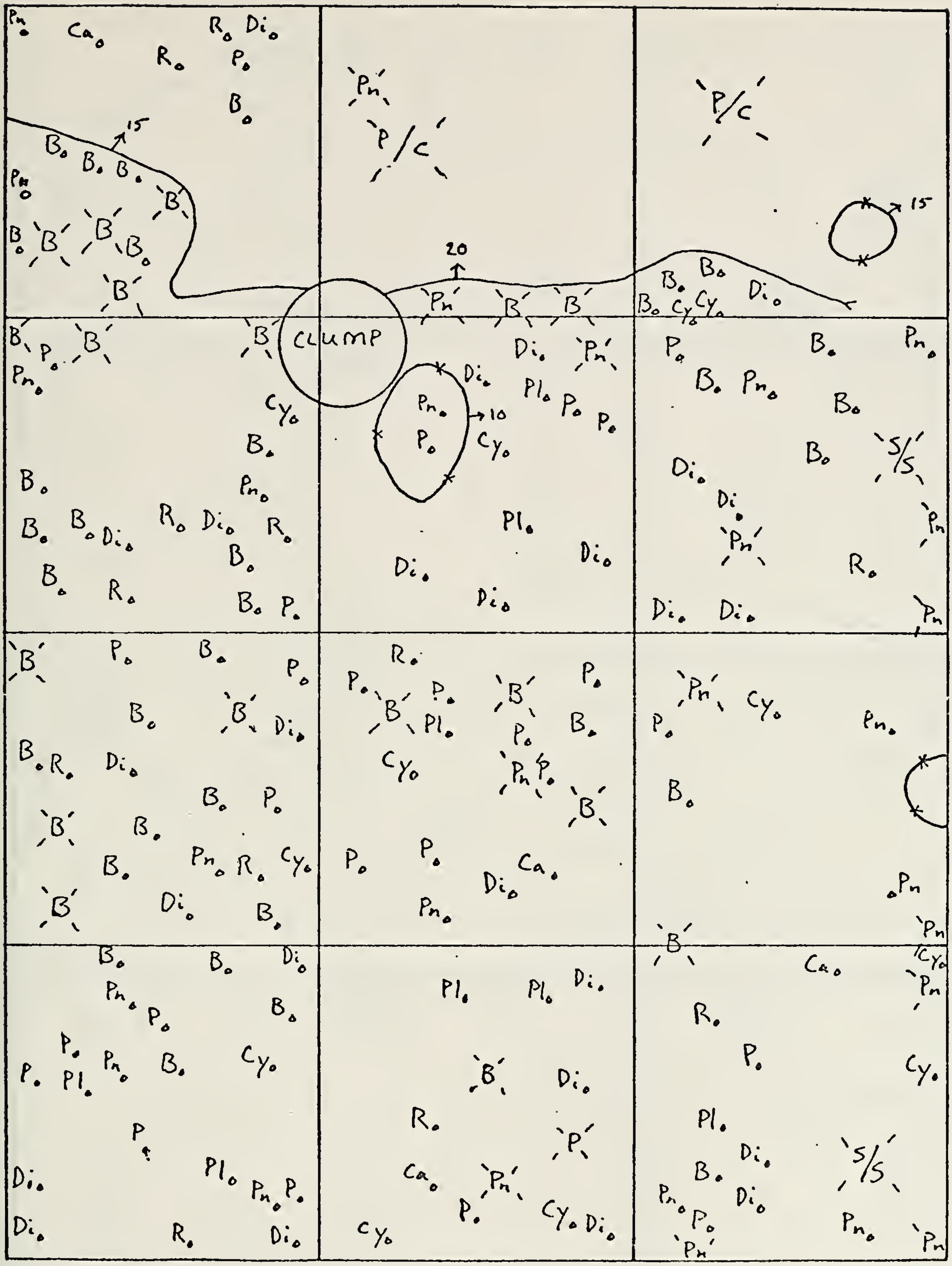
FIGURE B22



C-2K FIGURE B23 P-11



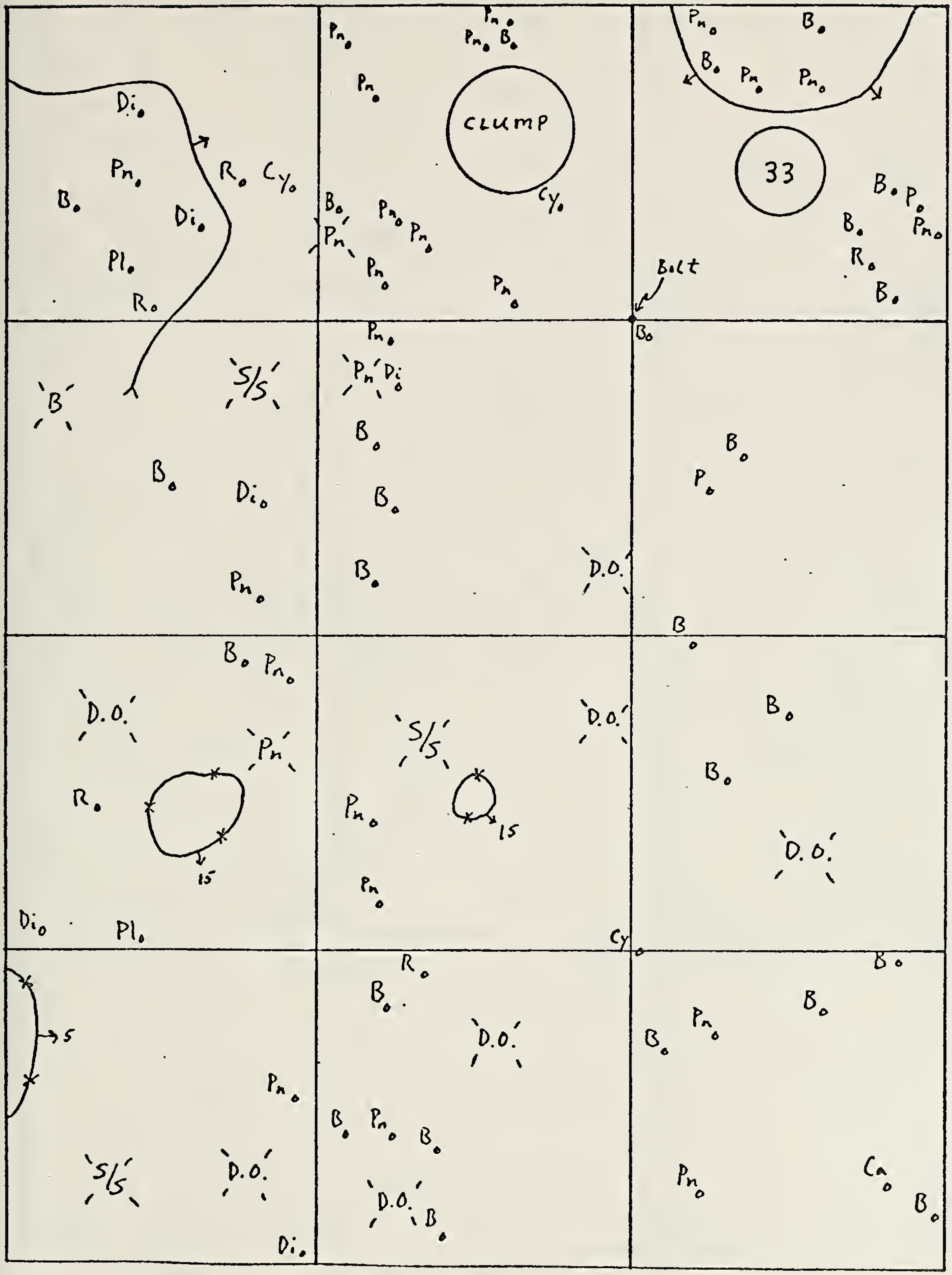
C-2K FIGURE B24 P-12



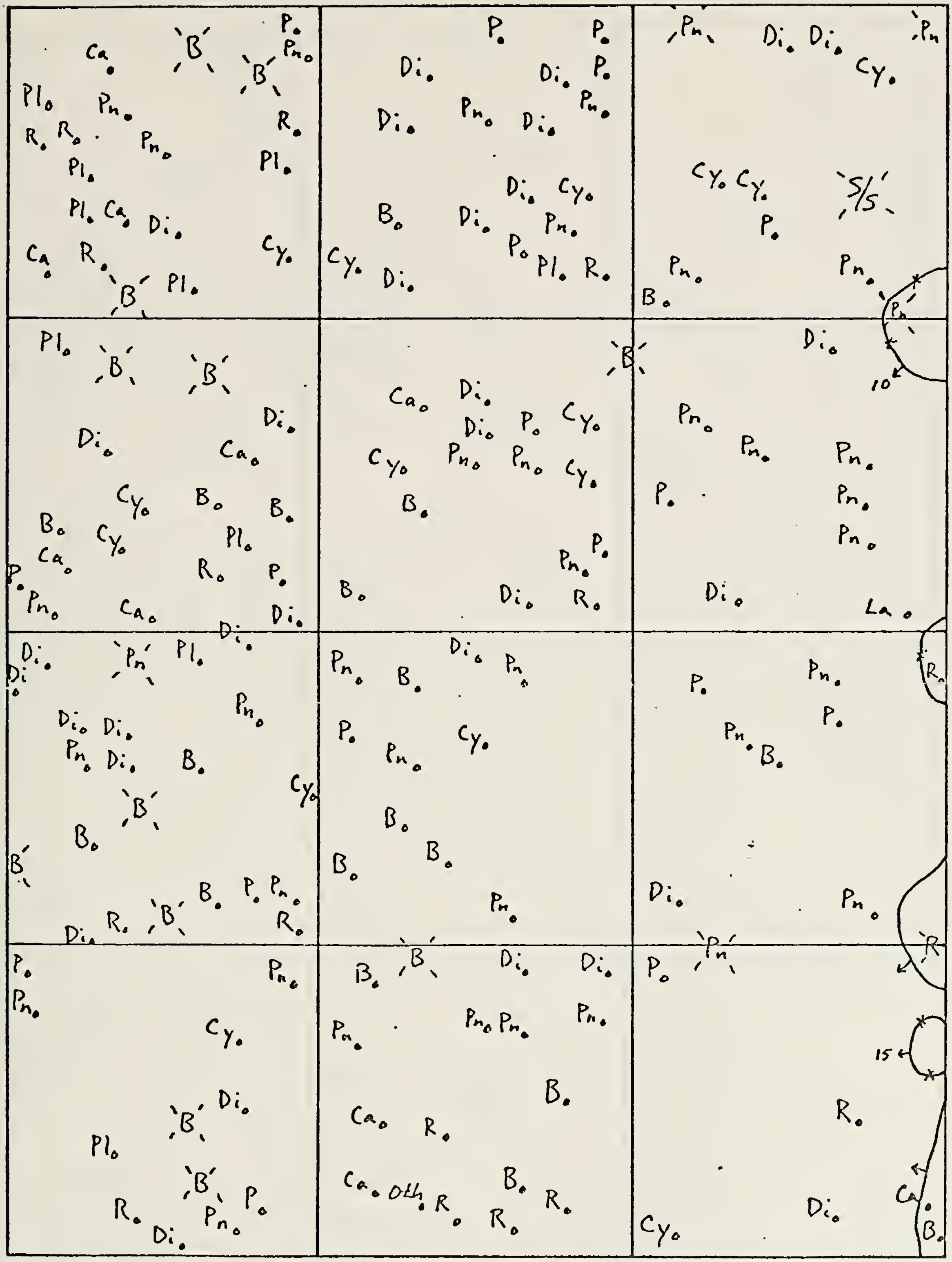
C-3K FIGURE B25 P-1

C-3K FIGURE B26 P-2

C-3K FIGURE B27 P-3



C-3K FIGURE B28 P-4



C-3K FIGURE B29 P-5

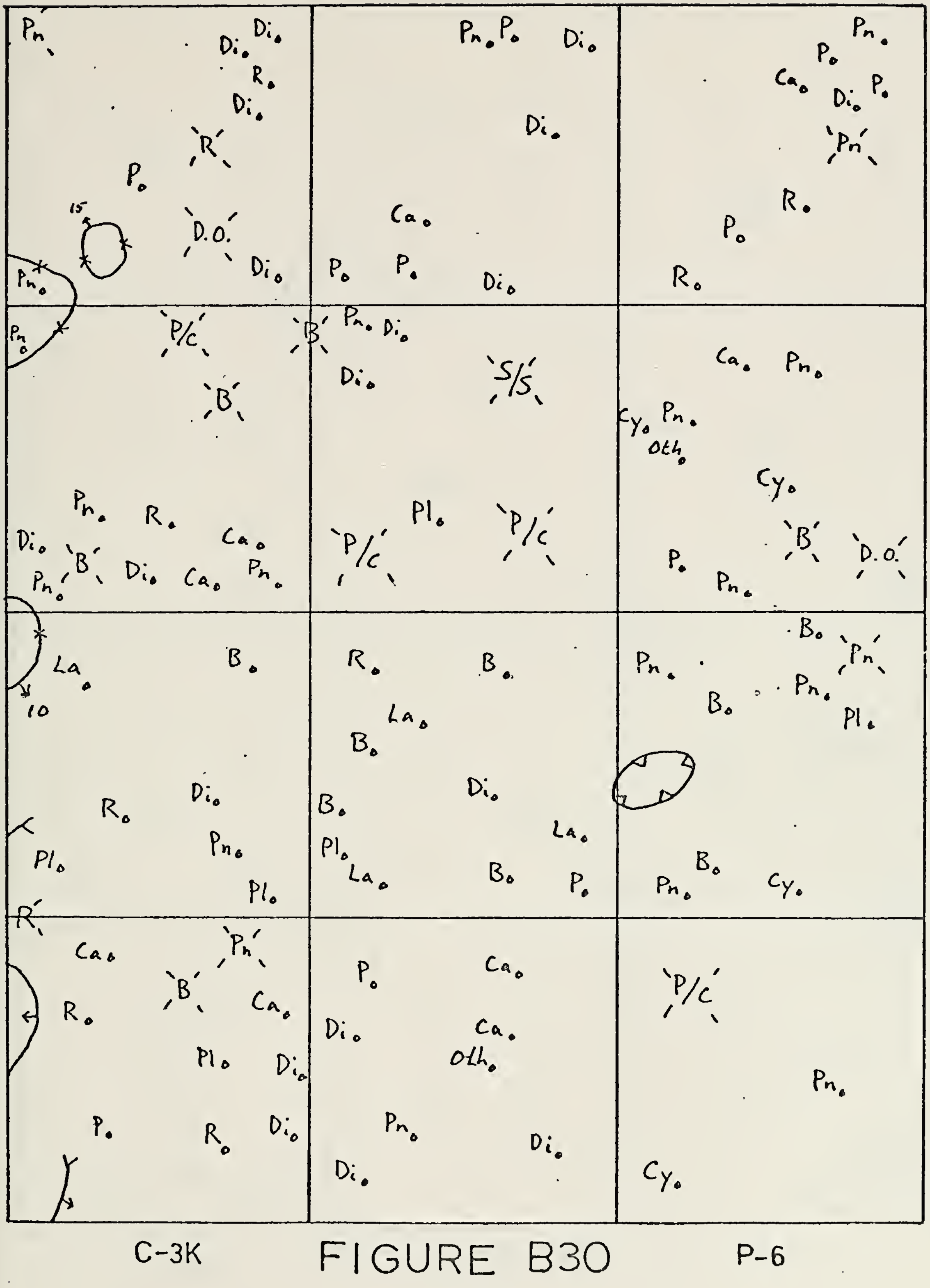

Pn Di Di R Di R P D.O. Di Pn Pn 15
Pn P Di Di Ca P P Di
Pn P Ca Di P Pn R P R
P/C B B Pn Di Di
S/S Pl P/C P/C
Ca Pn Cy Pn Oth Cy B D.O. P Pn
Pn R Di B Di Ca Ca Pn Pn
La B 10 R Di Pl Pn Pl
R B La B Di B La Pl La B P
B Pn Pn B Pl B Pn Cy
R Ca Pn B R Ca Pl Di P R Di
P Ca Di Ca Oth Pn Di Di
P/C Pn Cy
C-3K
P-6

FIGURE B30

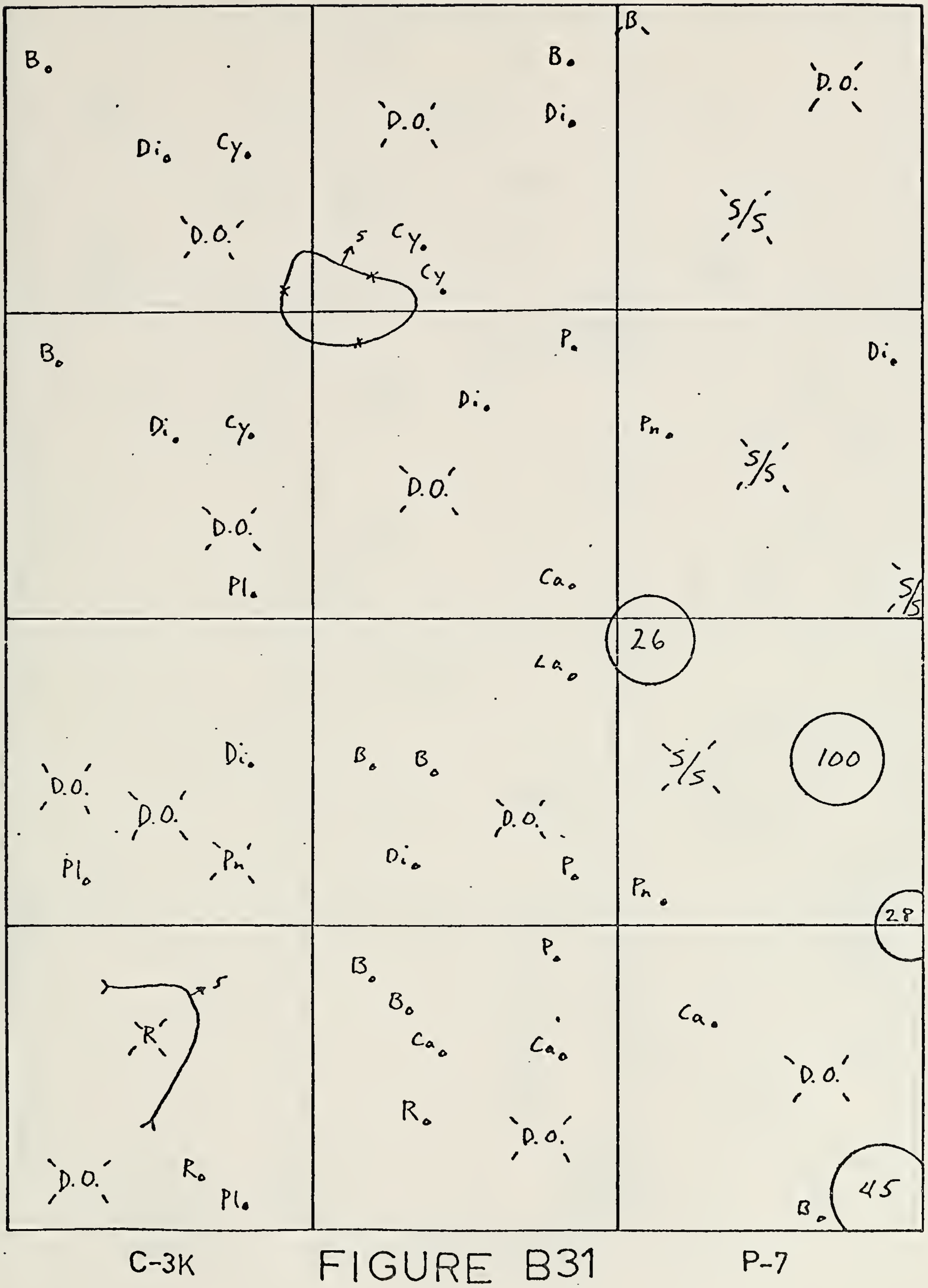
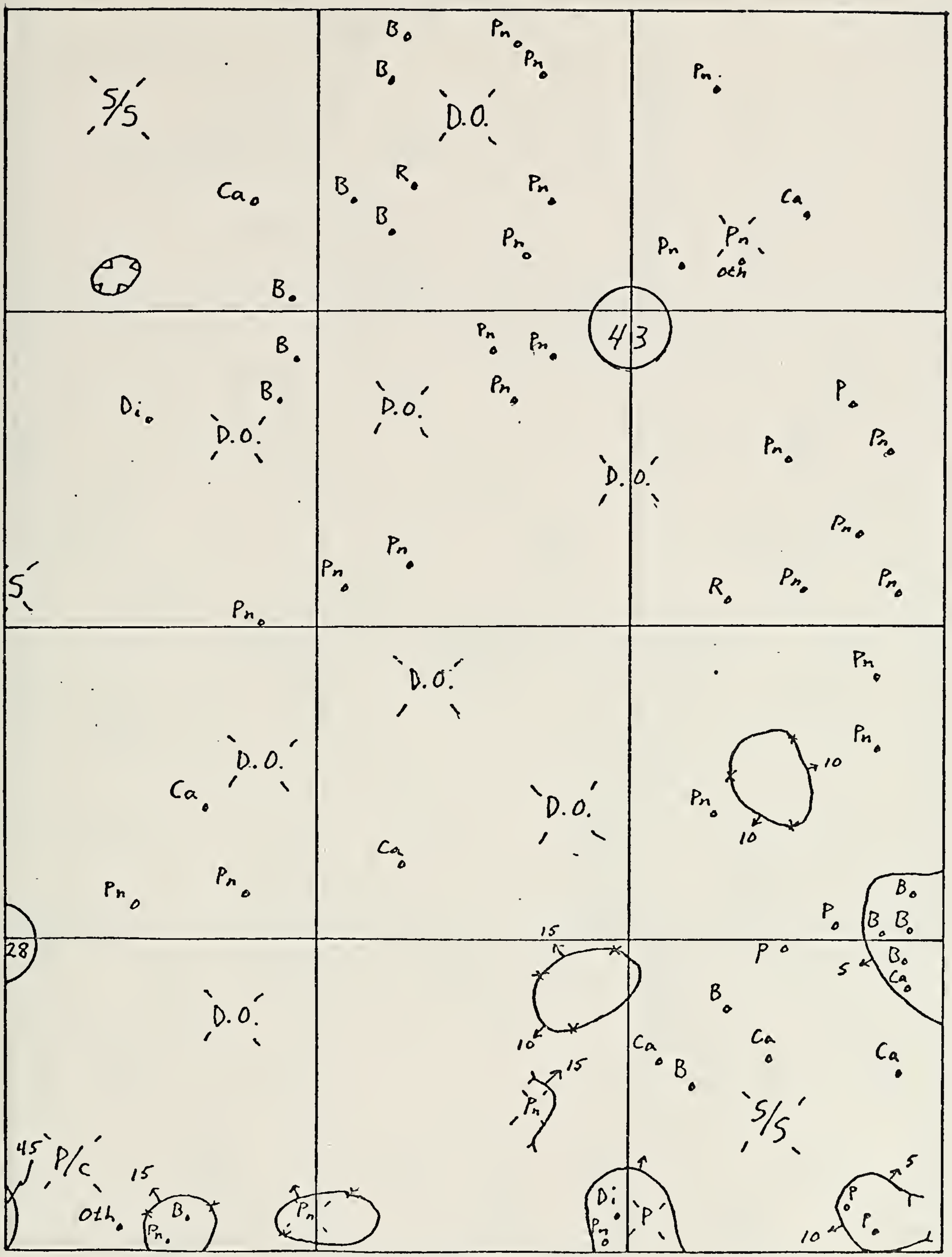
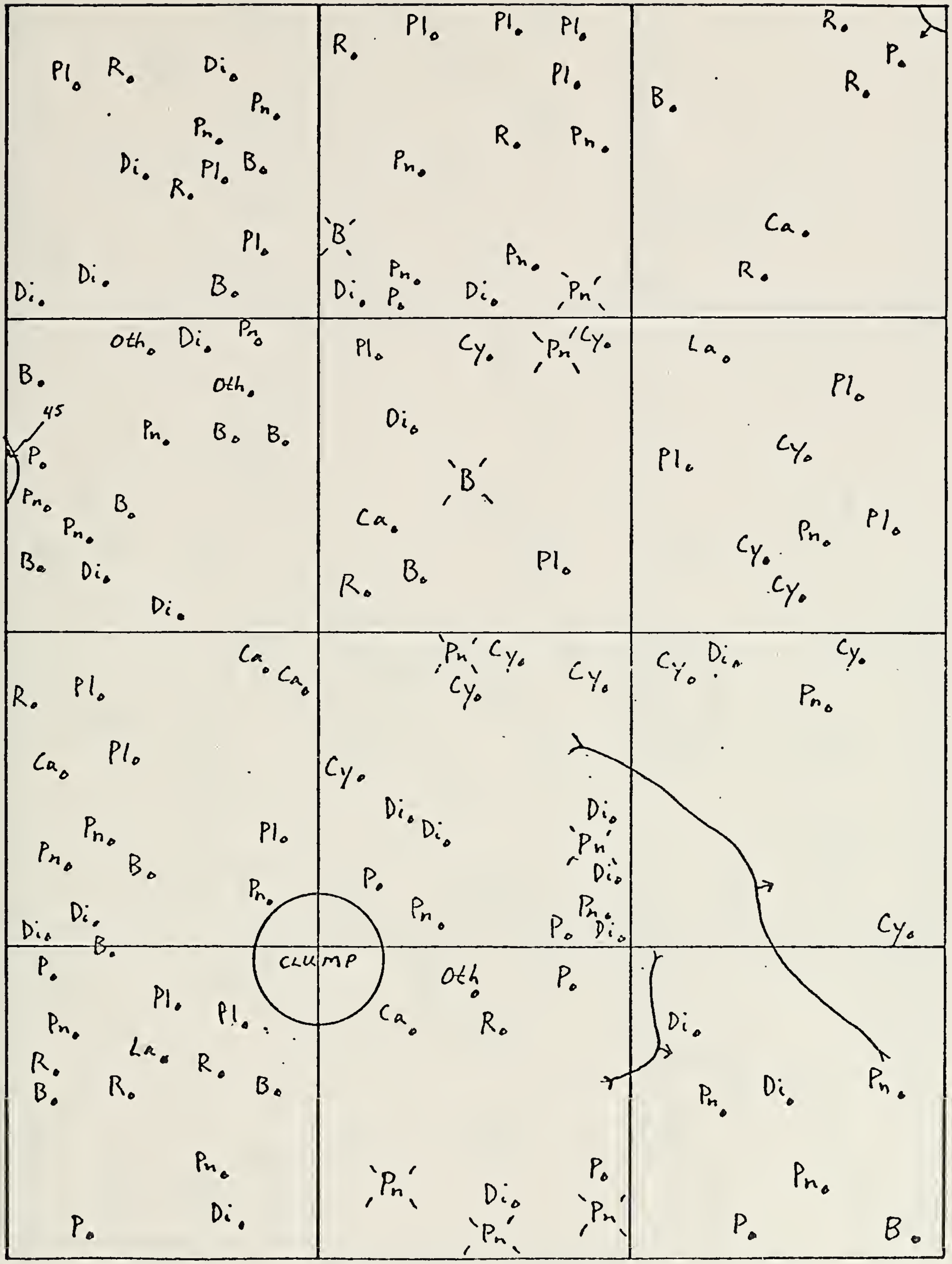


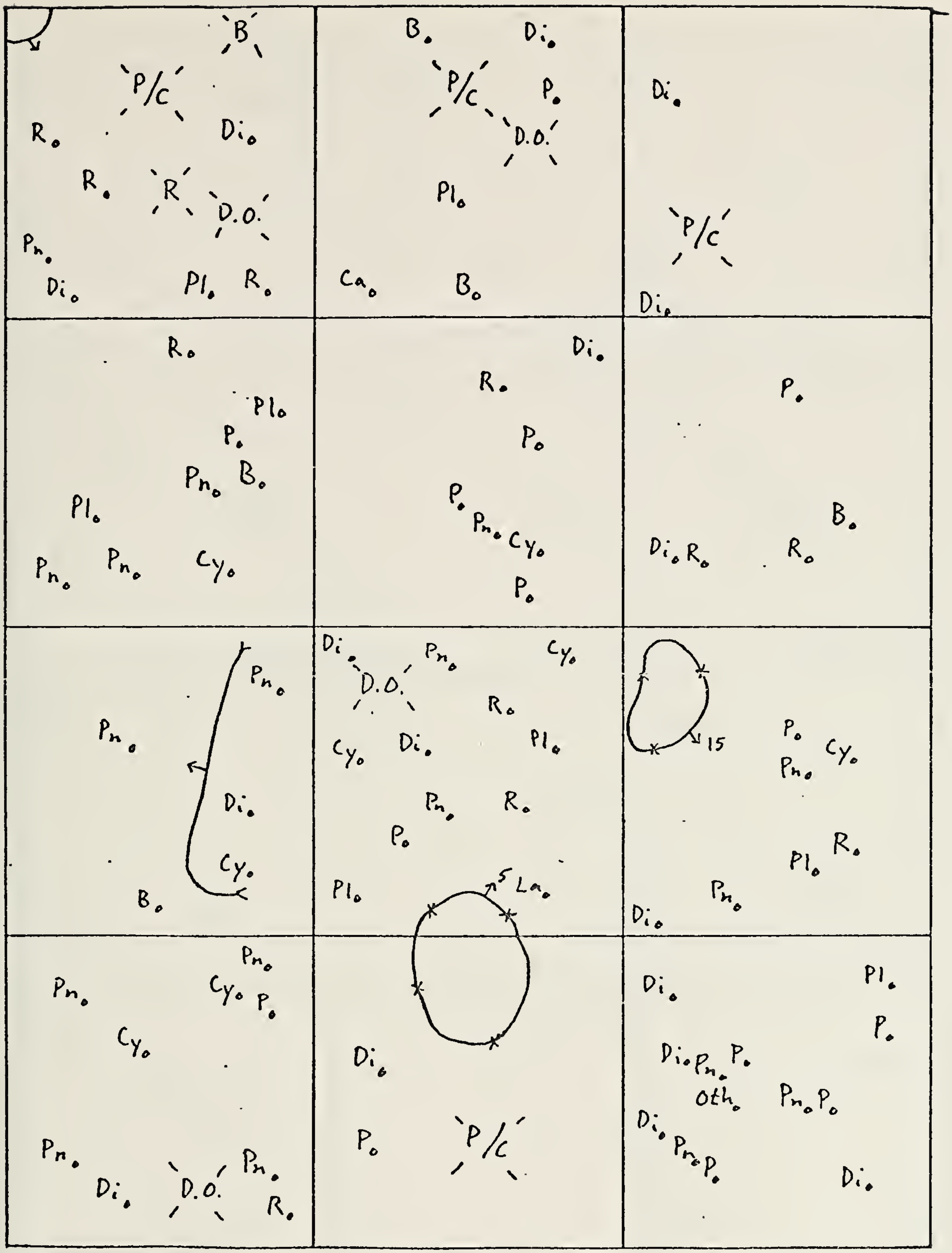
FIGURE B31



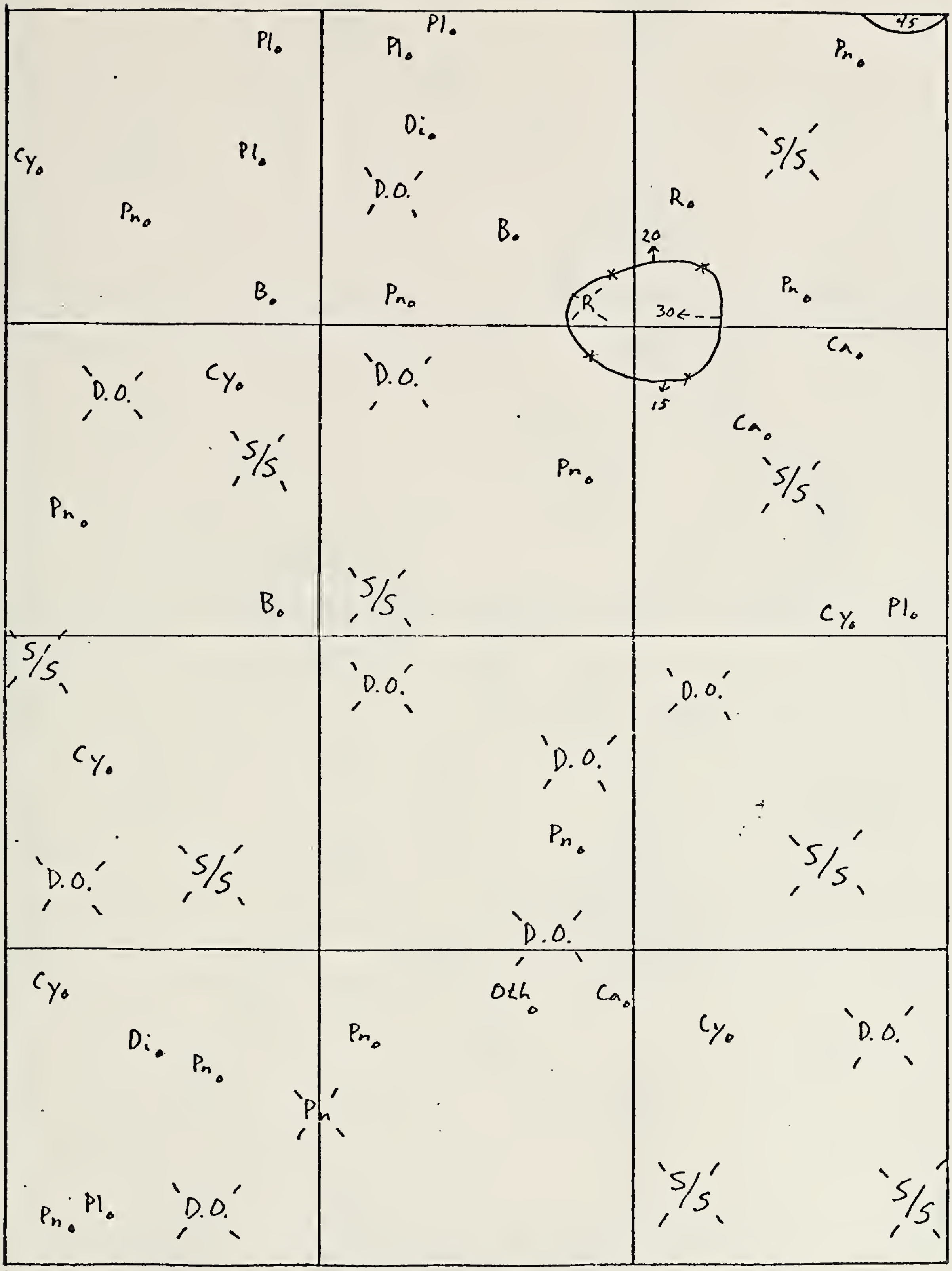
C-3K FIGURE B32 P-8



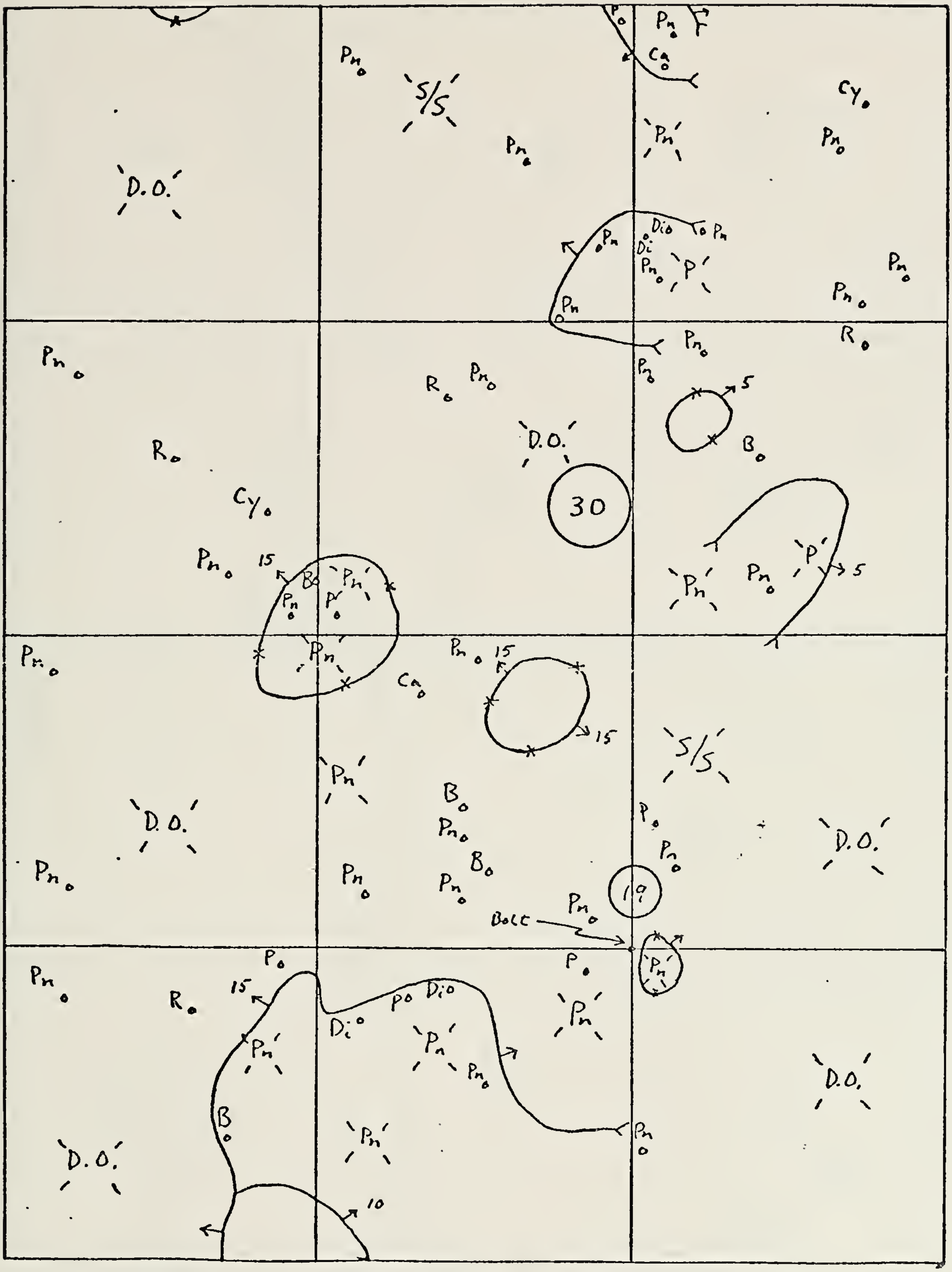
C-3K FIGURE B33 P-9



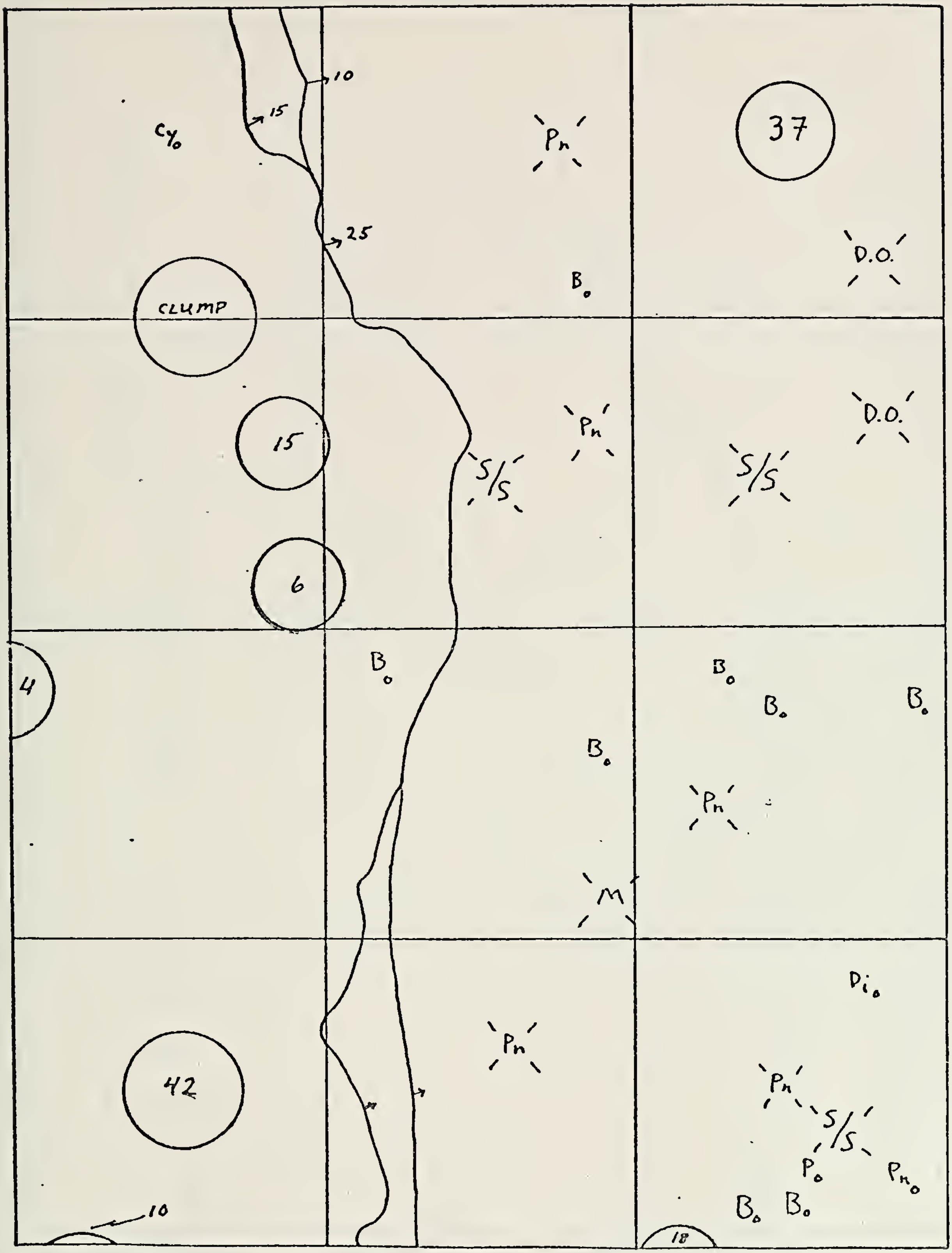
C-3K FIGURE B34 P-10



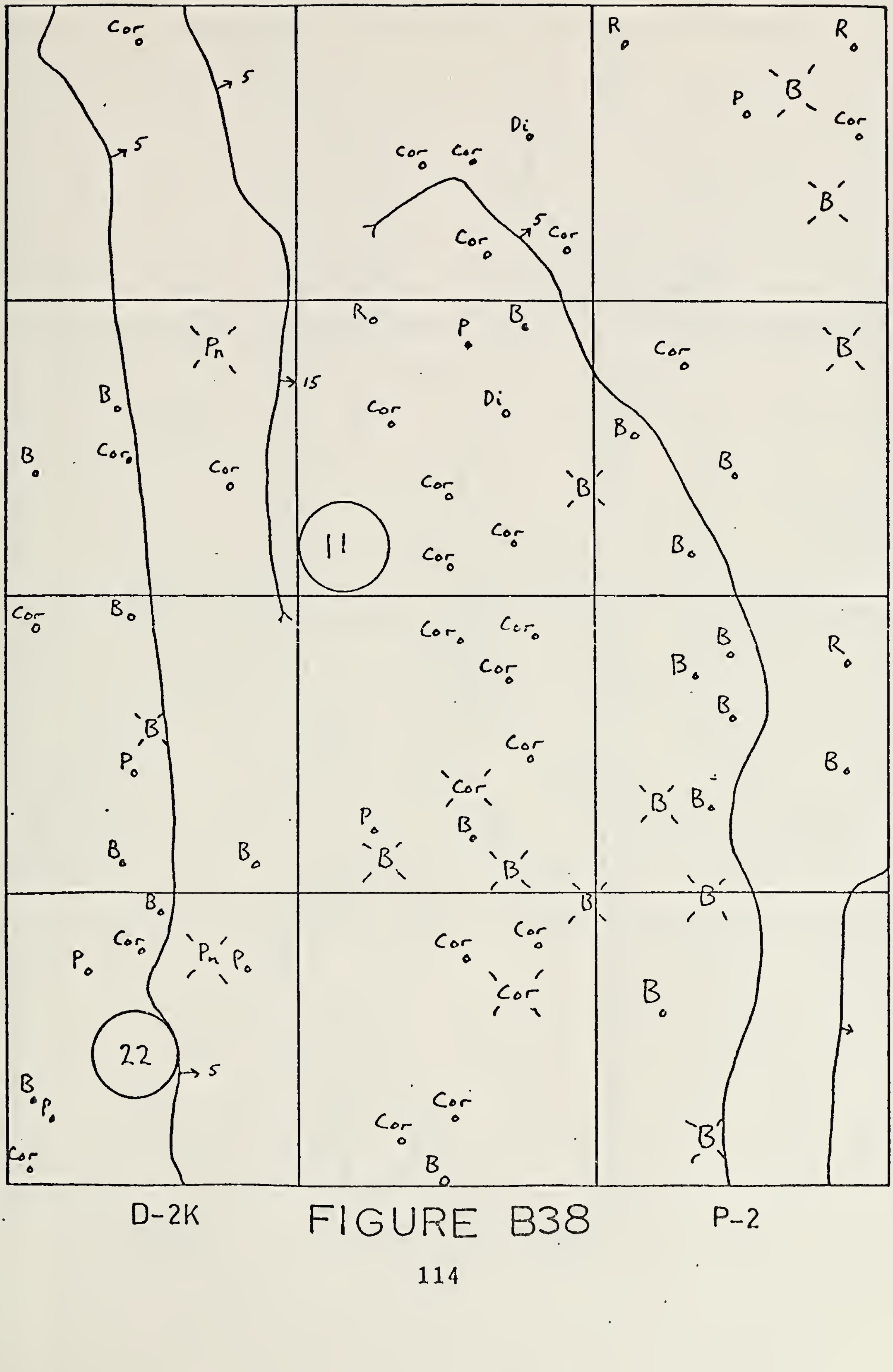
C-3K FIGURE B35 P-11



C-3K FIGURE B36 P-12



D-2K FIGURE B37 P-1



D-2K FIGURE B38 P-2

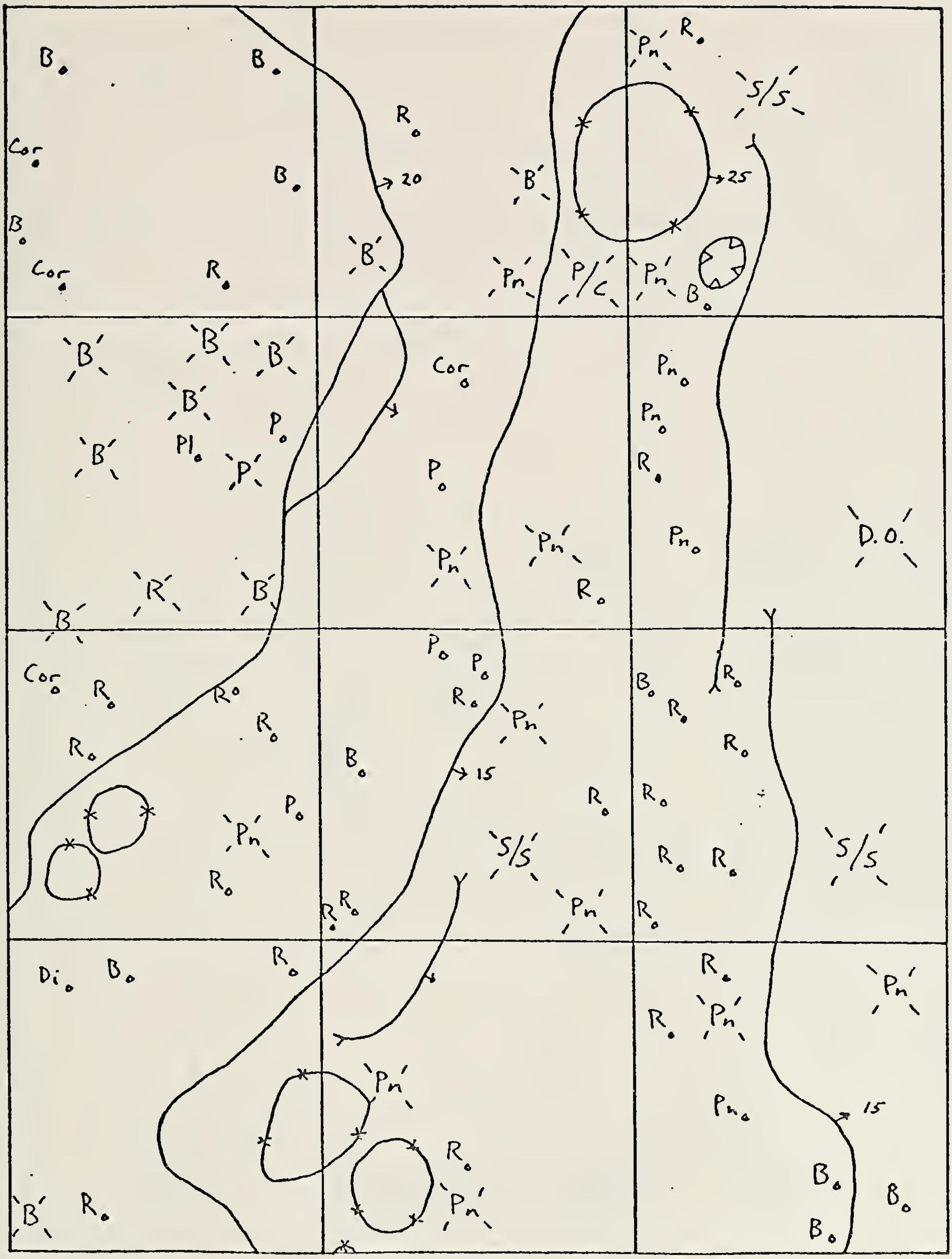
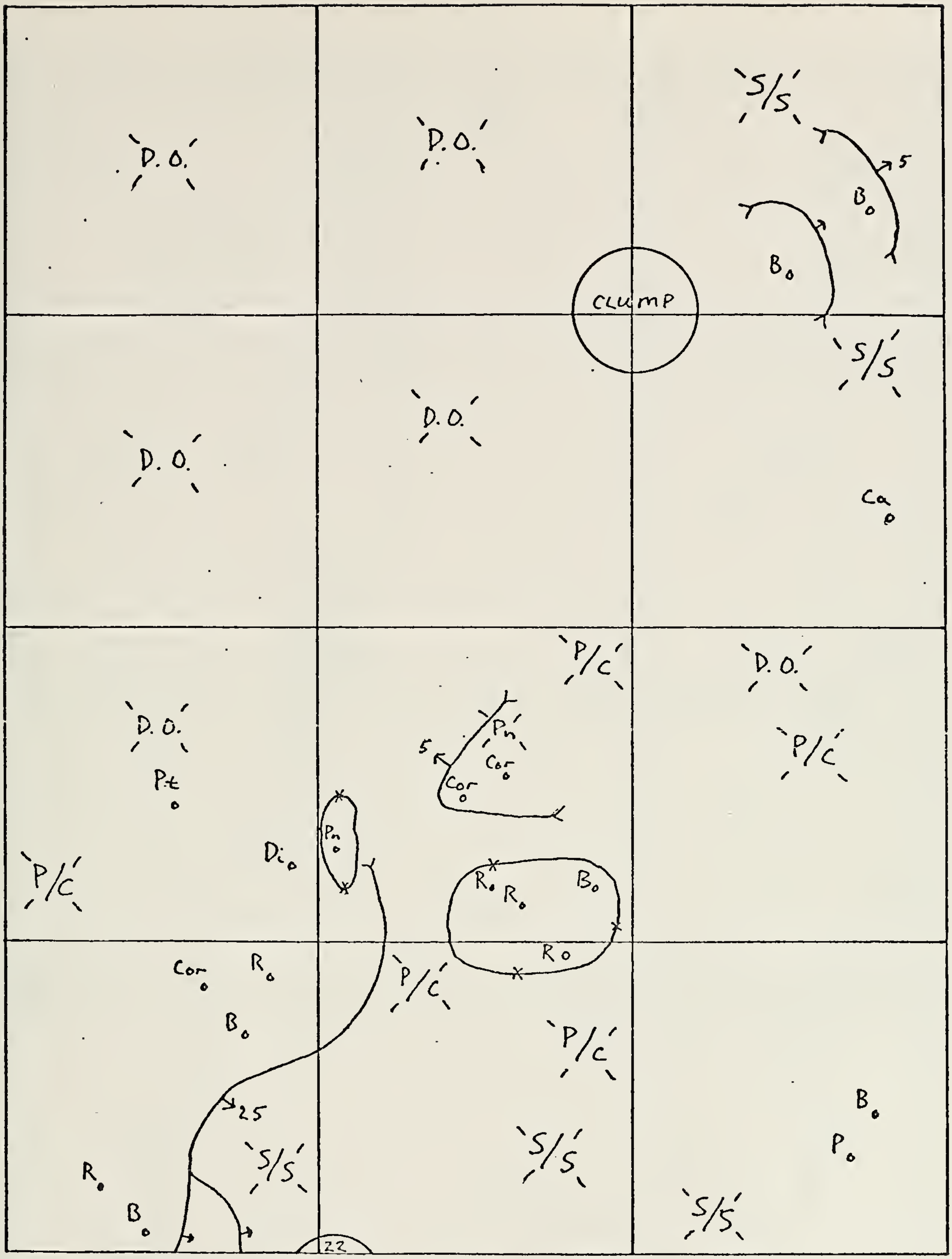
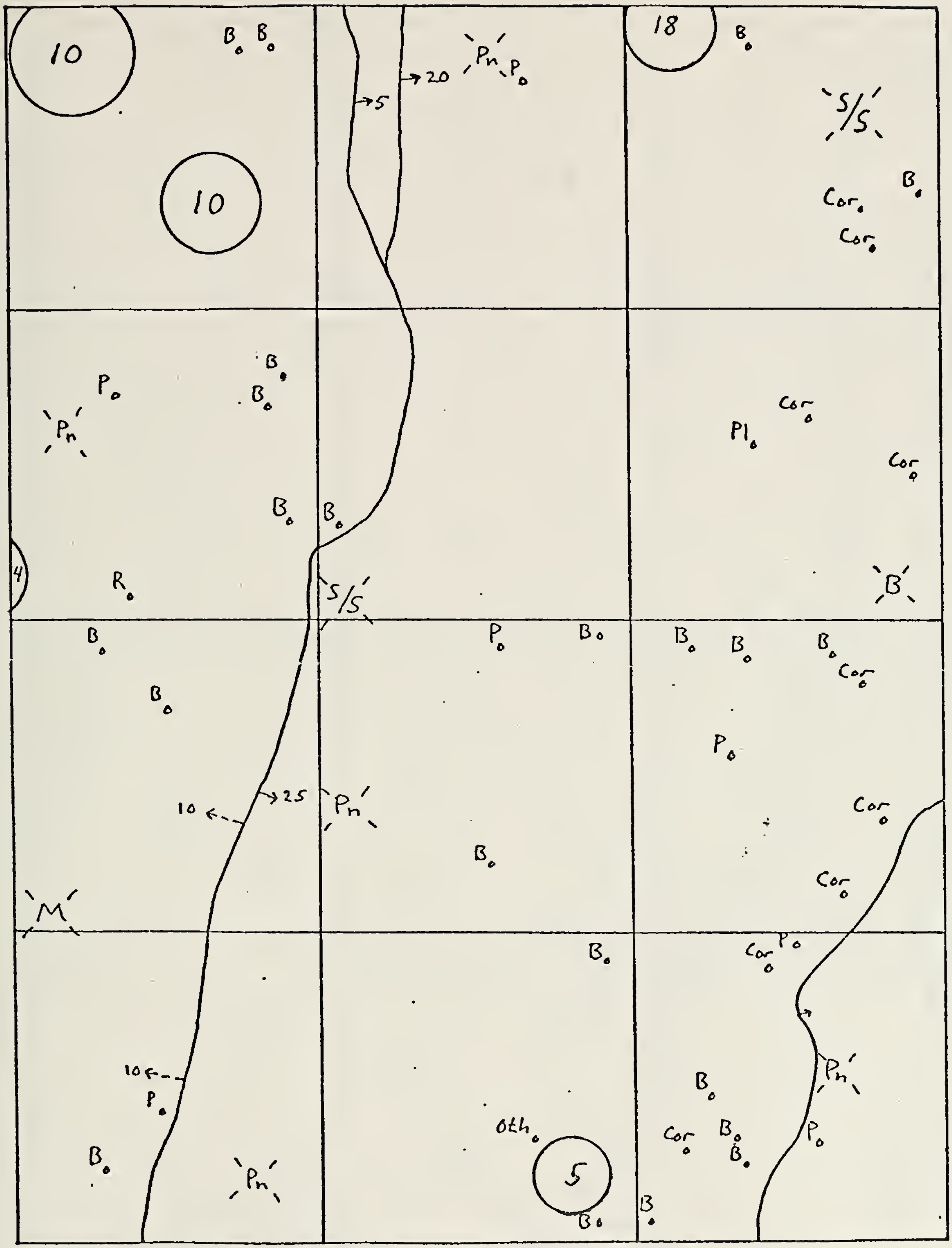


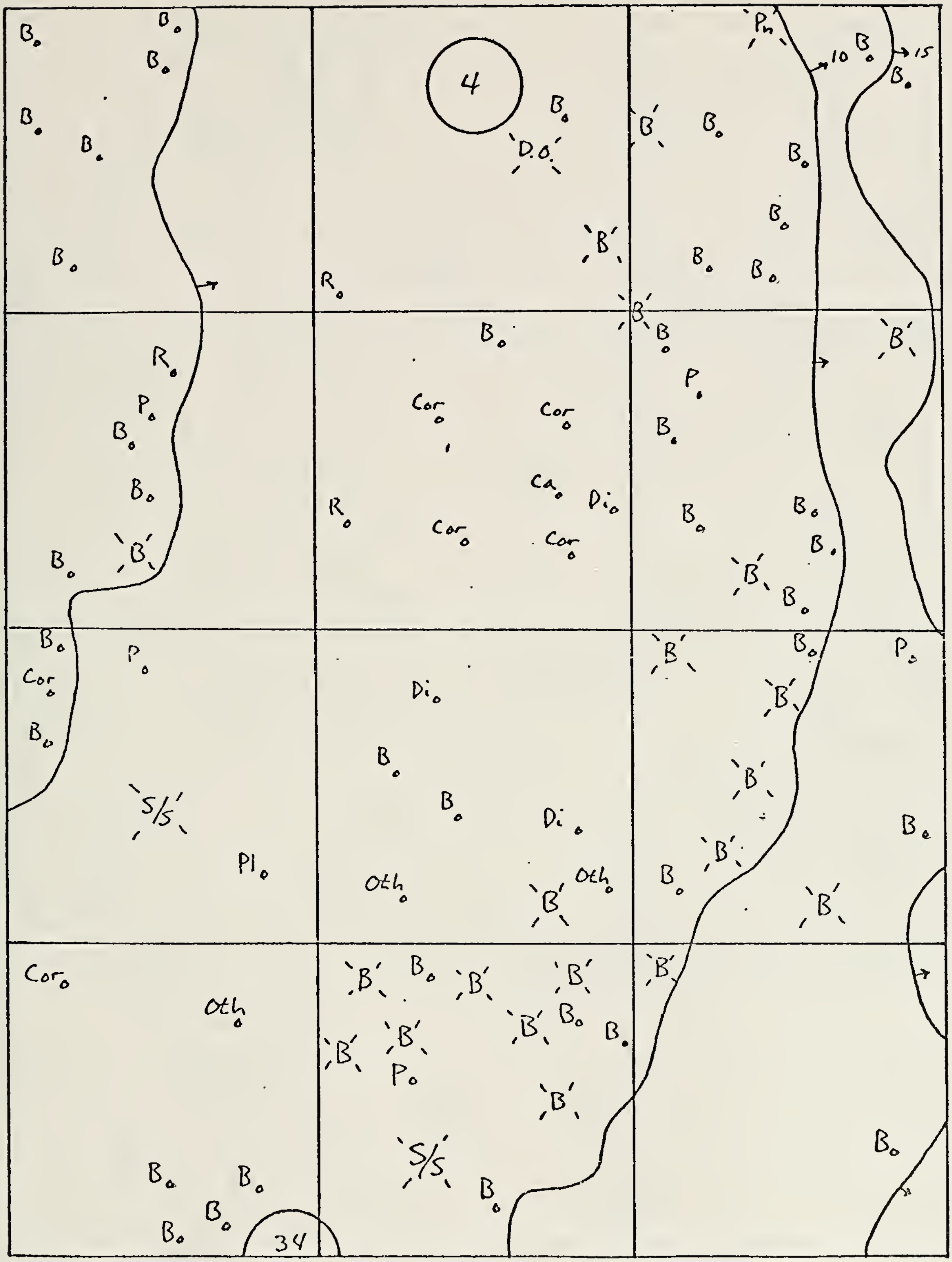
FIGURE B39



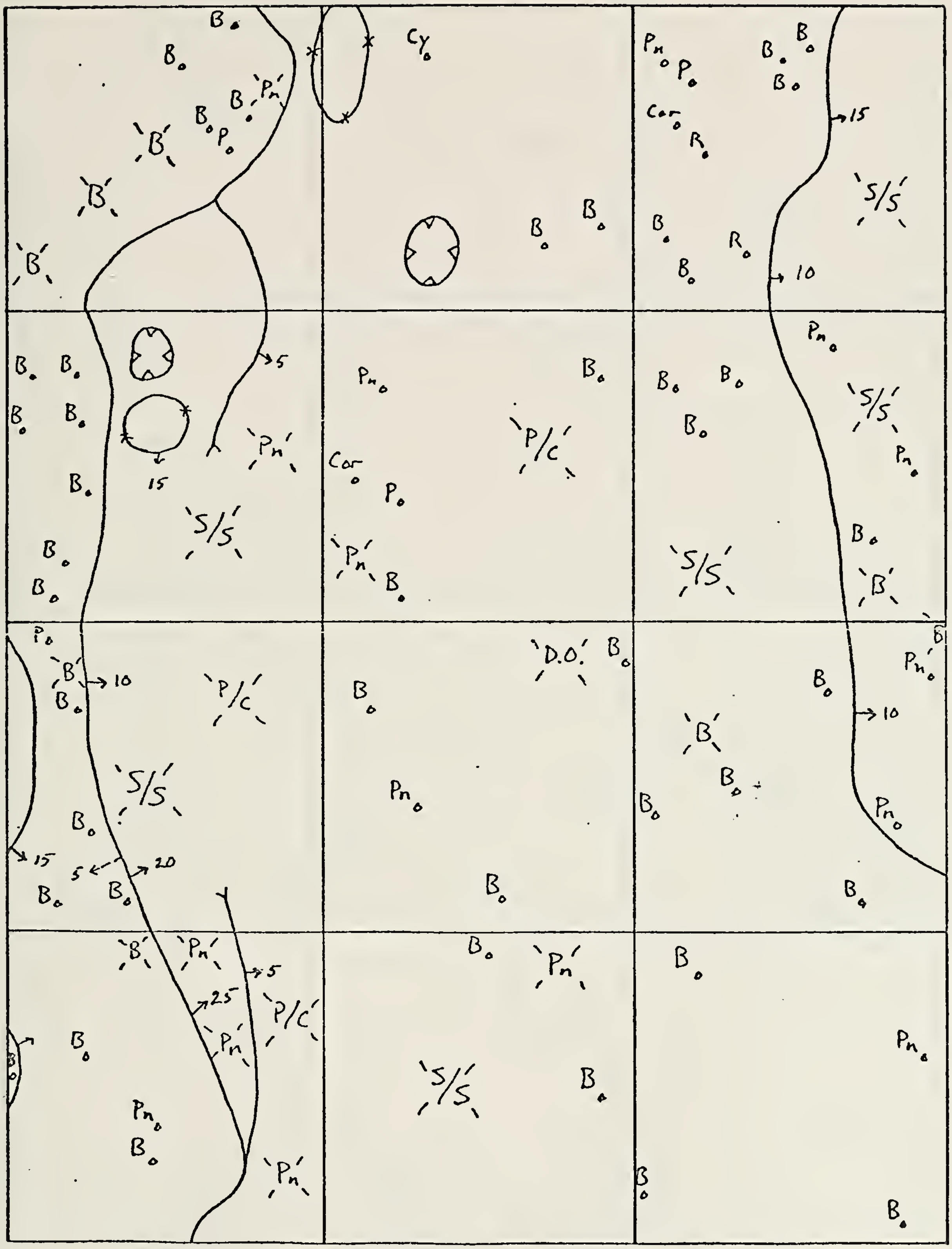
D-2K FIGURE B40 P-4



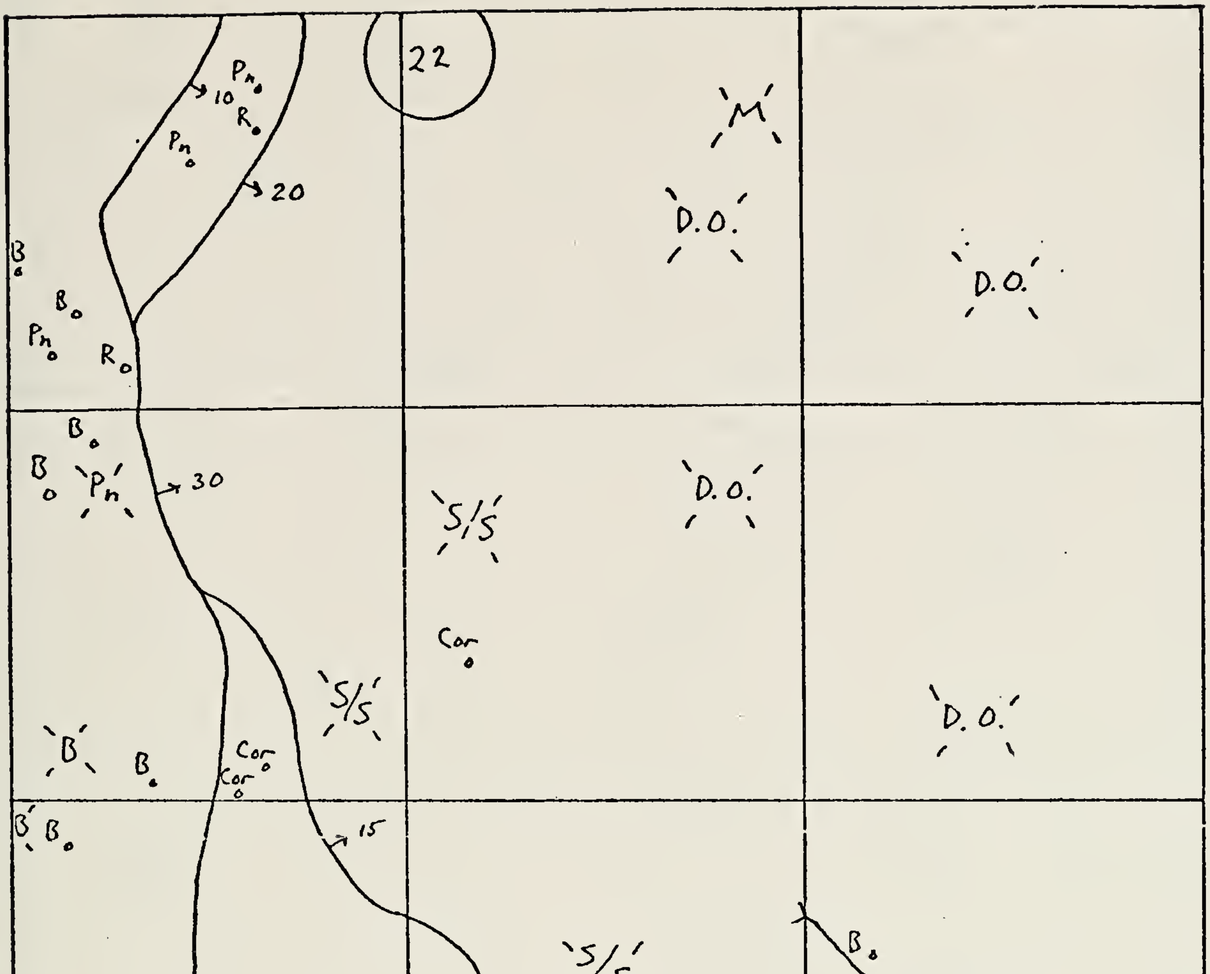
D-2K FIGURE B41 P-5



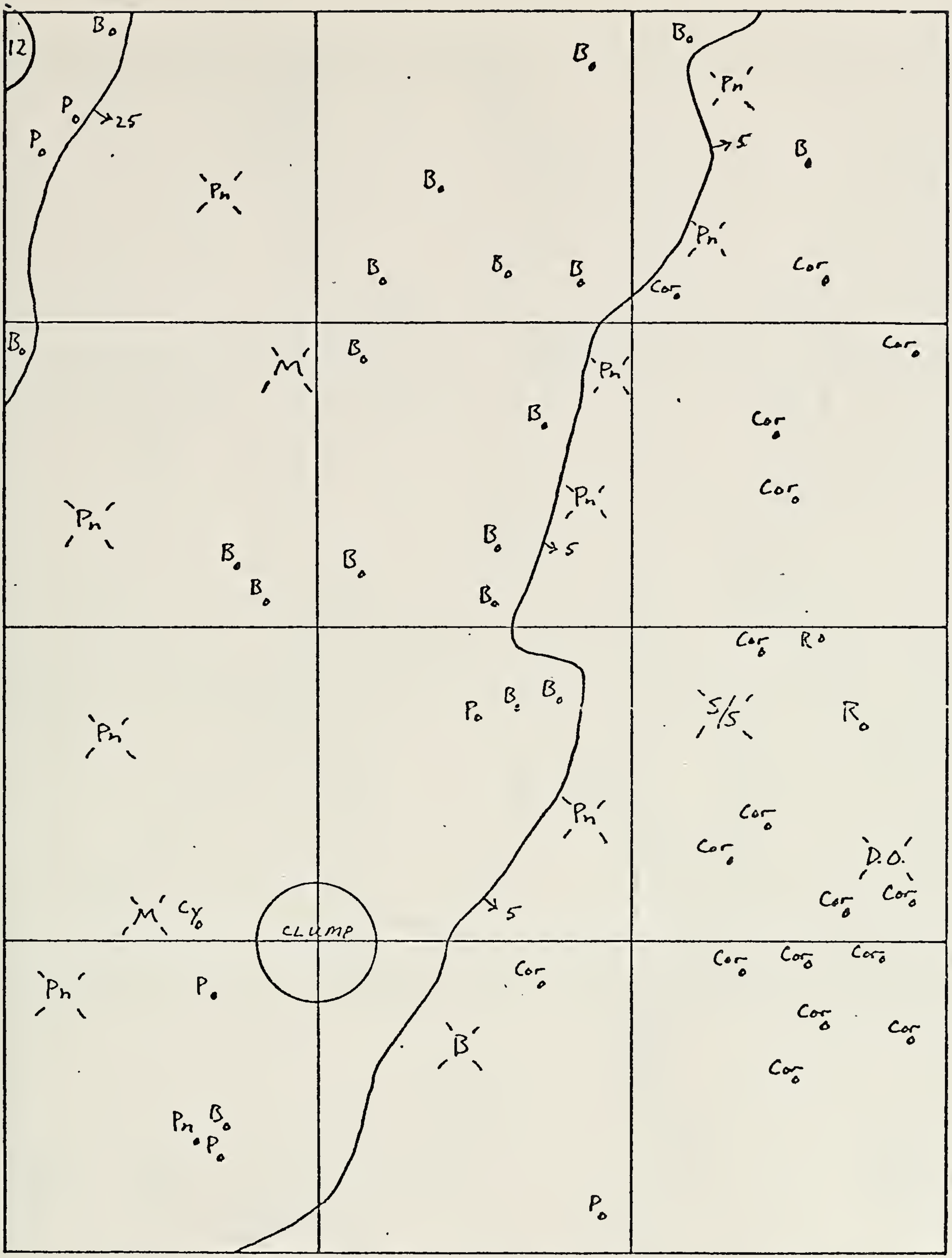
D-2K FIGURE B42 P-6



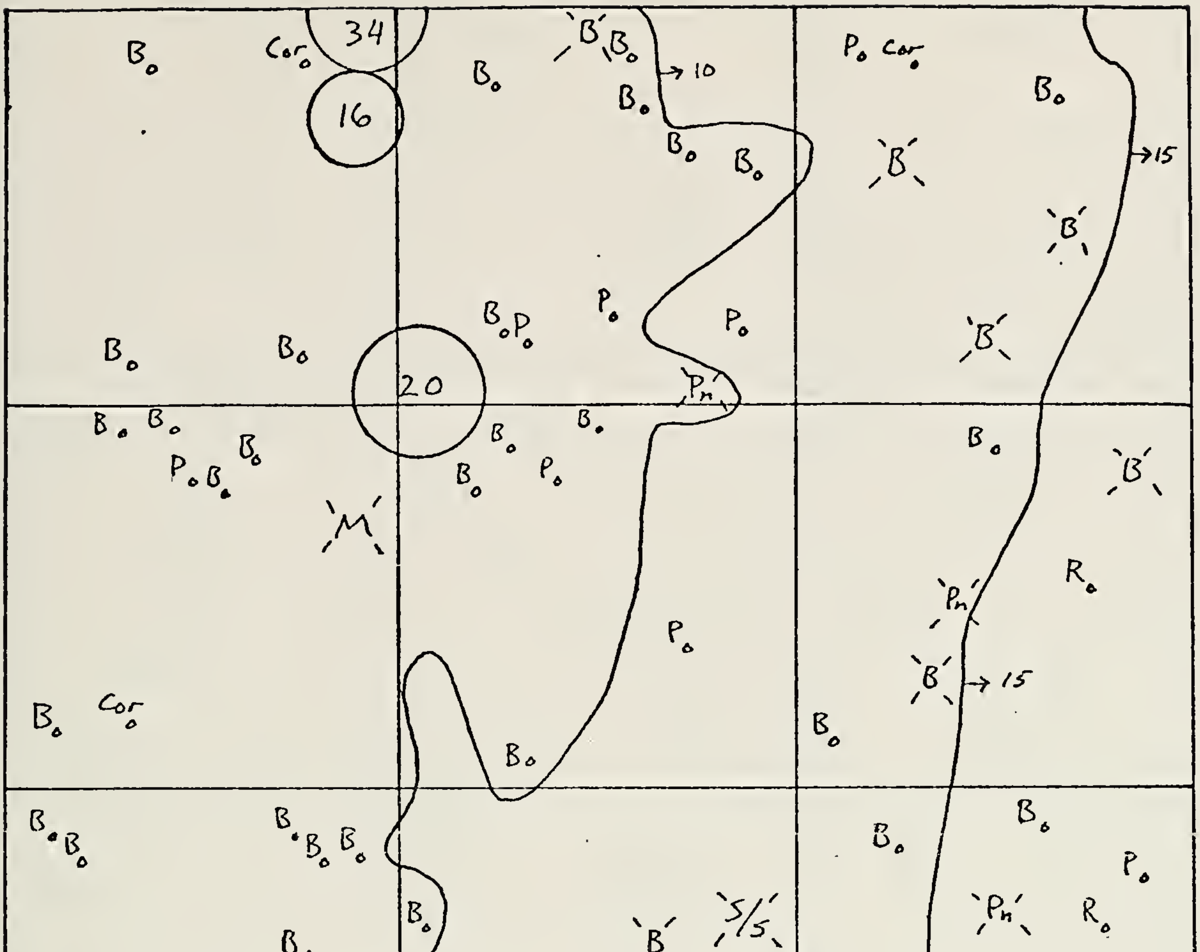
D-2K FIGURE B43 P-7



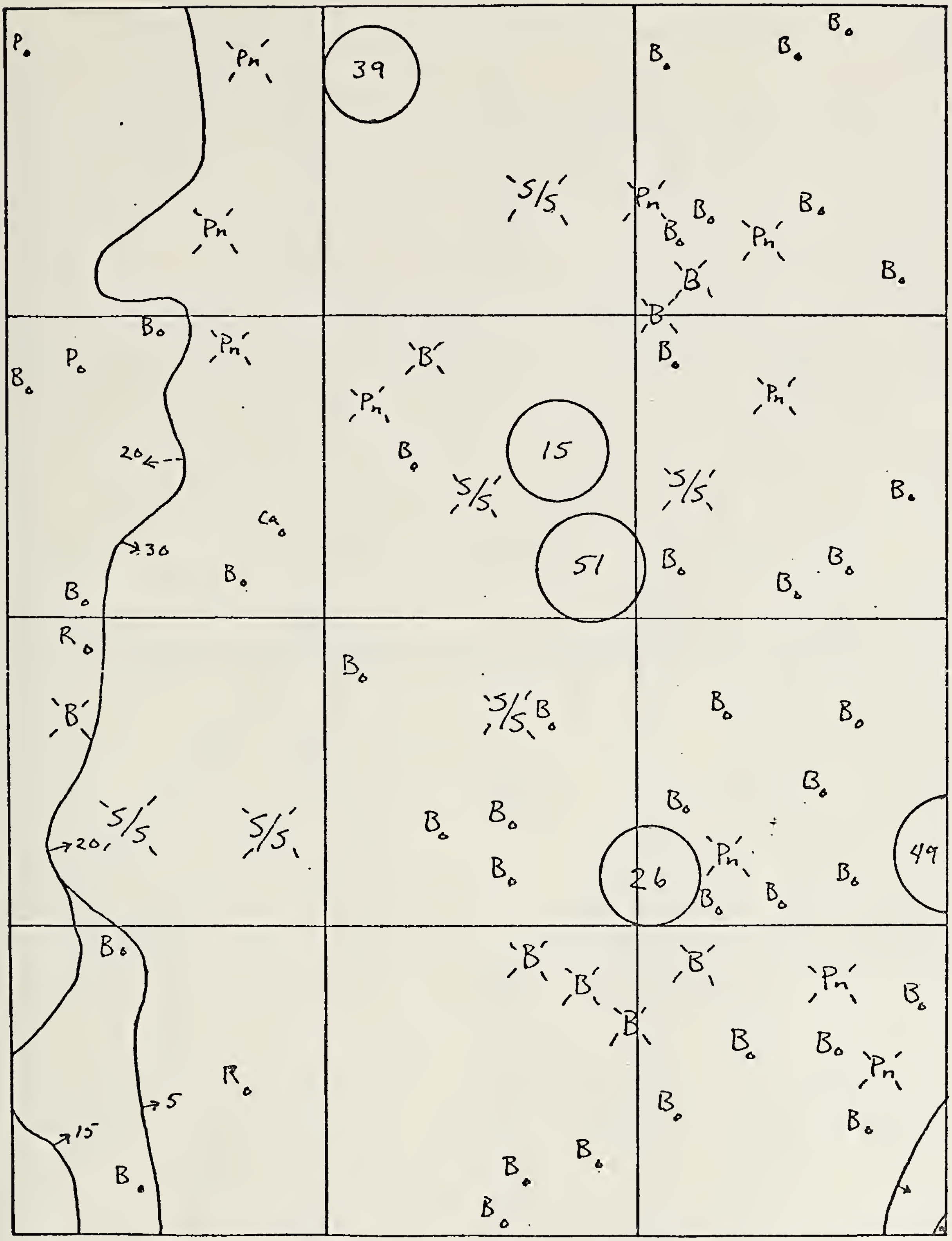
D-2K FIGURE B44 P-8



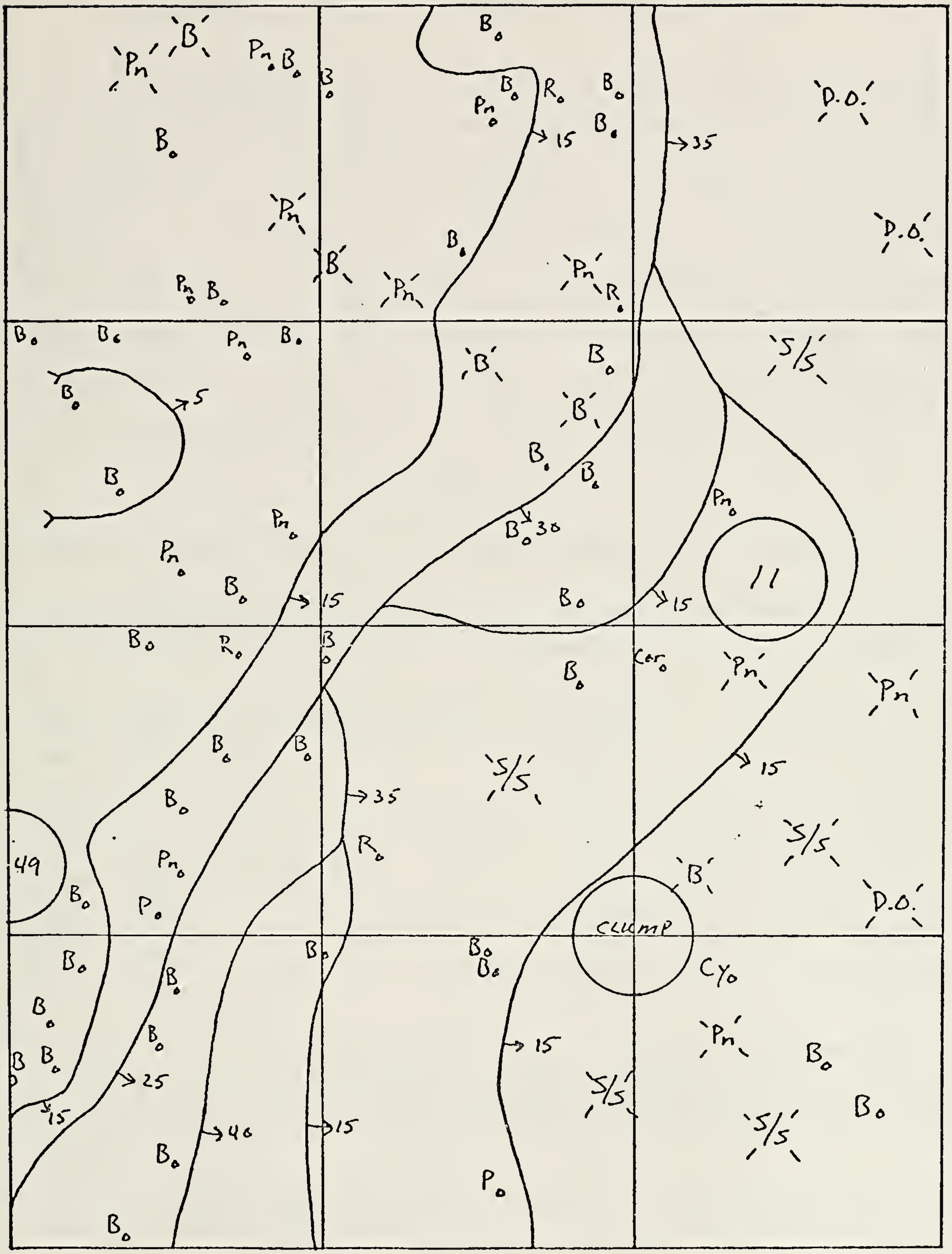
D-2K FIGURE B45 P-9



D-2K FIGURE B46 P-10



D-2K FIGURE B47 P-11



D-2K FIGURE B48 P-12

APPENDIX C: SOME ENVIRONMENTAL MEASUREMENTS

A time series record of significant wave heights (highest 17 of 50 observed waves), bottom horizontal visibility, and surface/bottom temperature differences is shown in Figs. C1 and C2. In general, the records suggest a positive correlation between low wave heights, strong temperature differences, and longer underwater horizontal visibility distances. Unfortunately, winter measurements were limited to just one short sequence and only one quadrat location.

TABLE C1

Winter/Summer Surface and Bottom Temperature Analysis*

Months	Jan/Feb 74	Jun/Jul 74
Mean Temperature Difference**	1.0°C	3.0°C
Mean Max. Temp.	13.0	15.0
Mean Min. Temp.	11.5	12.0
Max. Temp. Difference	2.0	6.0
Min. Temp. Difference	0.0	1.0
Max. Temp.	14.5	16.5
Min. Temp.	12.0	10.0
No. Observations	7	26

*Due to statementsof Davis (1974), and comparative measurements taken by this investigator, temperatures taken at any quadrat on any given day could be considered representative of the kelp beds as a whole.

**i.e., mean temperature difference of surface temperature minus bottom temperature.

TABLE C2

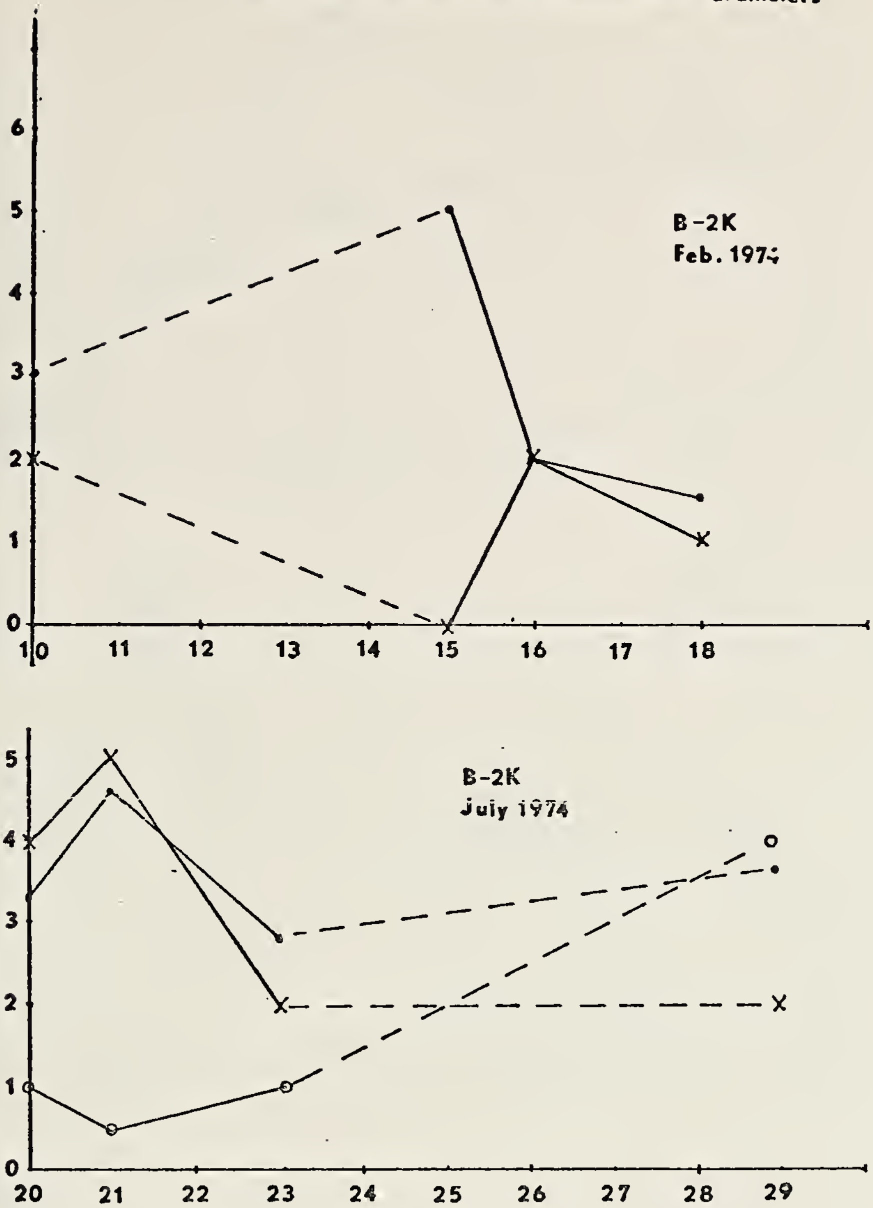
Quadrat Comparisons of Underwater Bottom Horizontal Visibility*

Quadrat	B-2K(W)	B-2K(S)	C-2K(S)	C-3K(S)	D-2K(S)
Mean Vis.	3.1 m	3.6 m	3.1 m	4.6 m	3.2 m
Max. Vis.	5.0 m	4.6 m	3.6 m	7.0 m	4.6 m
Min. Vis.	1.5 m	2.8 m	2.5 m	2.0 m	1.9 m
No. Observations	5	5	6	11	7

(Time intervals considered were: Winter (W) = 5 Jan-18 Feb., 1974; and Summer (S) = 5 May-29 Jul., 1974).

*Distance at which a white writing slate (20 cm x 12 cm) disappears from view.

Time Series Plots of Some Environmental Parameters



KEY

Ordinate values:

o-o Observed significant wave heights (feet)

x-x Surface/bottom temperature difference (°C)

•-• Bottom horizontal visibility (m)

Abscissa values are consecutive days of the month.

FIGURE C1

Time Series Plots of Some Environmental Parameters

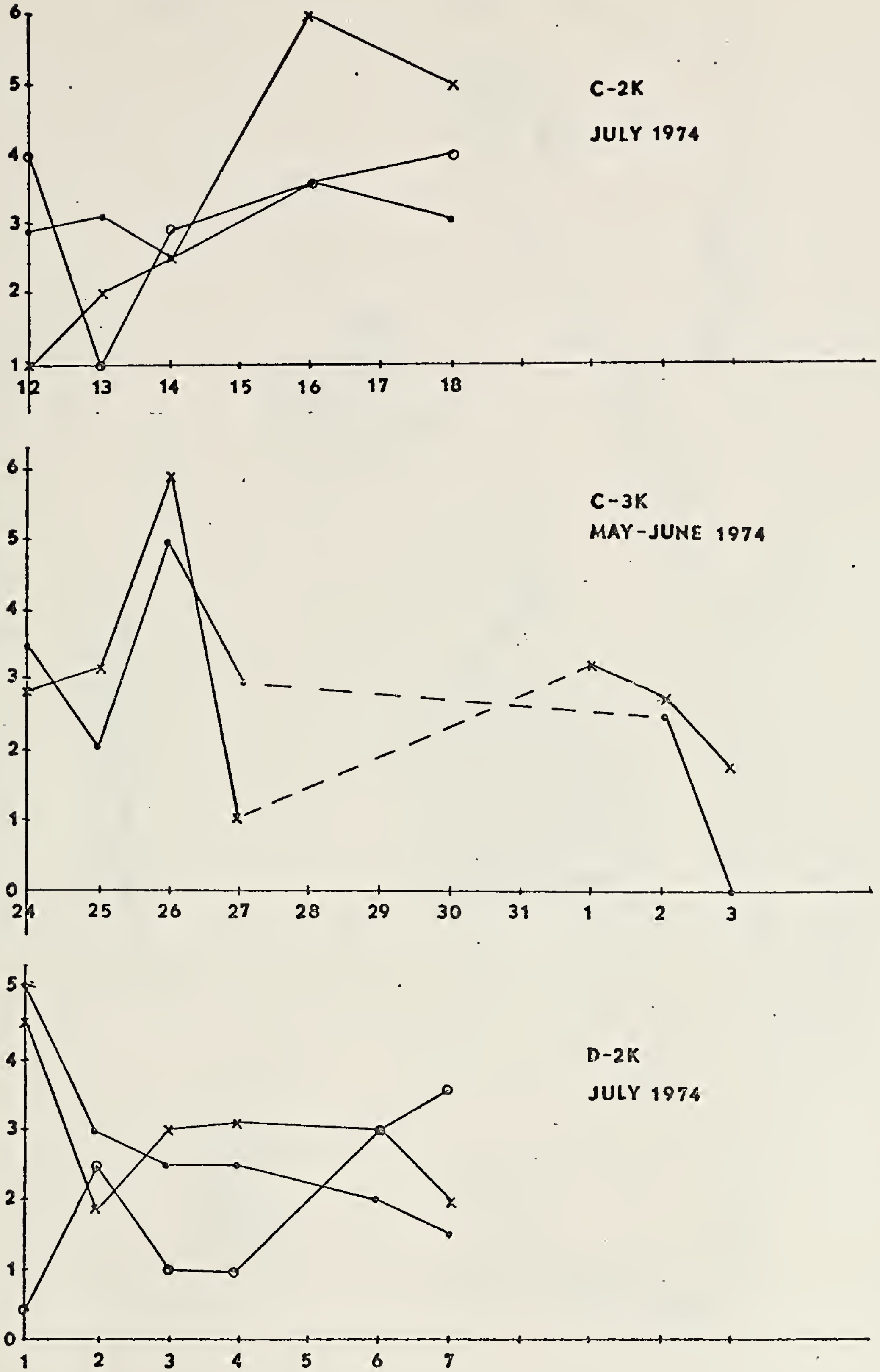


FIGURE C2

APPENDIX D: AERIAL PHOTOGRAPH REPRESENTATIONS

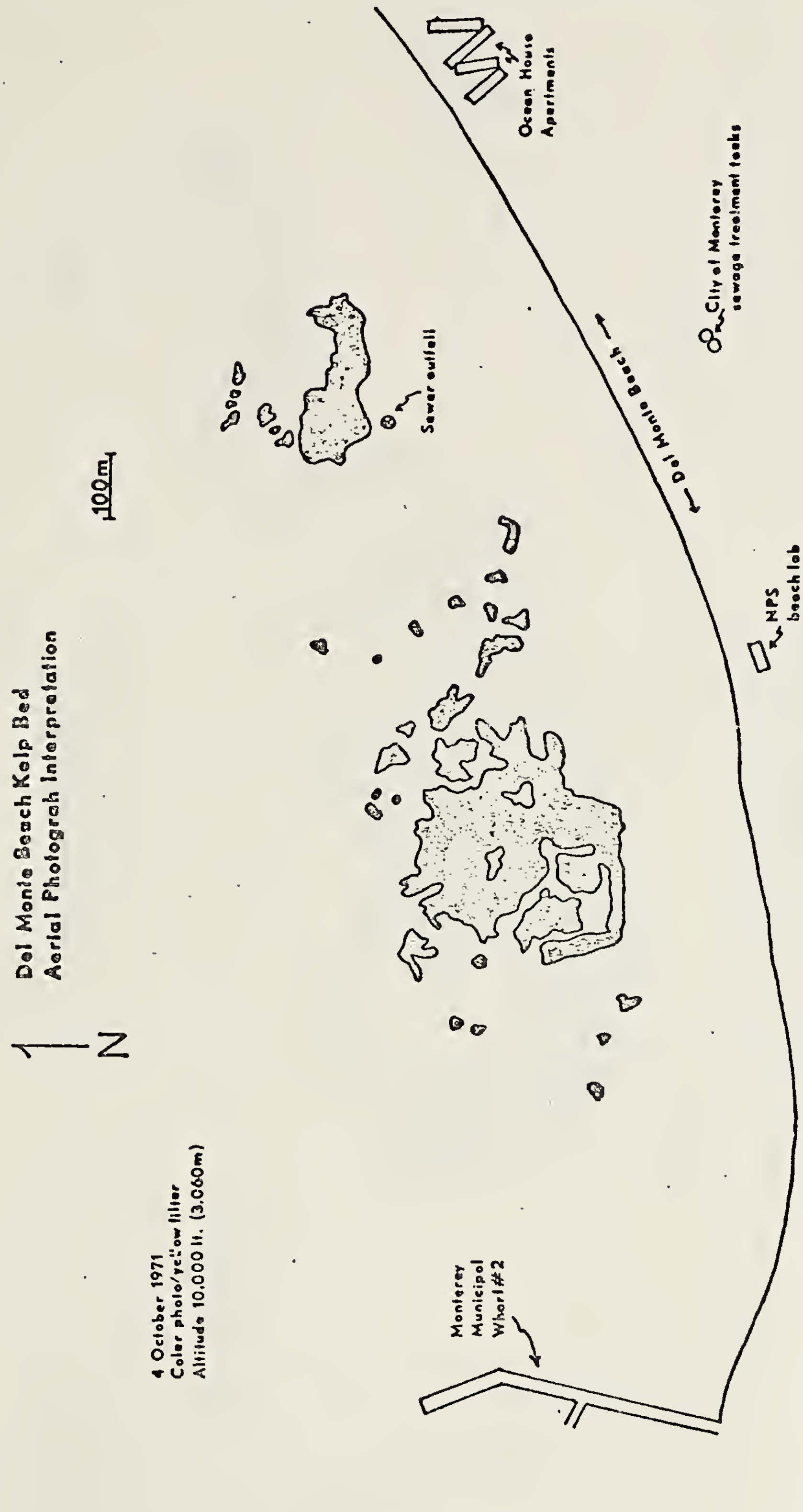


FIGURE D1


N
Del Monte Beach Kelp Bed
Aerial Photograph Interpretation
100m
13 December 1972
Color photo/yellow filter
Altitude 5,000 ft. (1,530m)

FIGURE D2


Del Monte Beach Kelp Bed
Aerial Photograph Interpretation
N
100m
11 September 1973
Color photo/yellow filter
Altitude 10,000 ft. (3,060m)

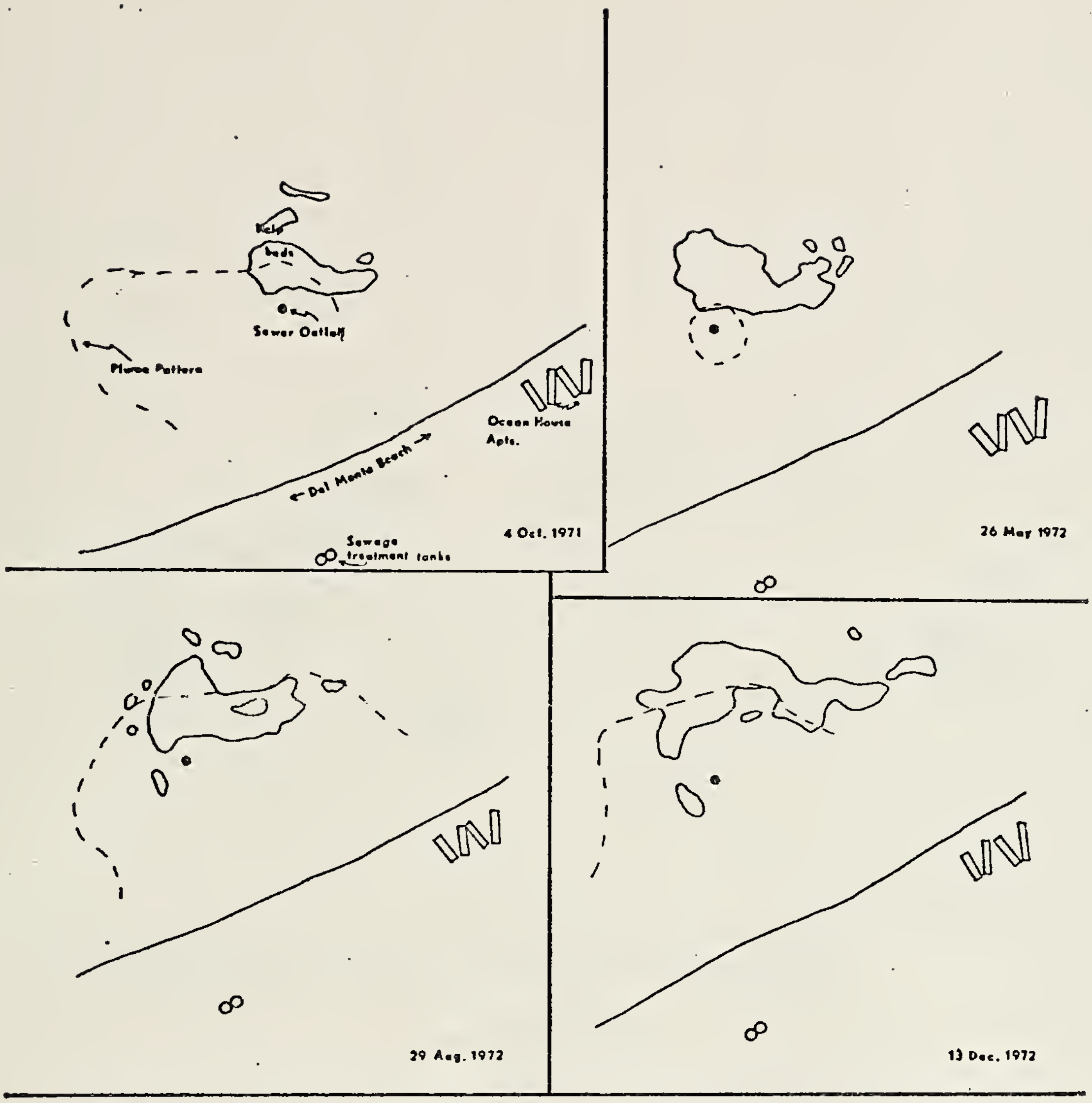
FIGURE D3


N
Del Monte Beach Kelp Bed
Aerial Photograph Interpretations
100m
1 January 1974
Color photo/yellow filter
Altitude 10,000 ft. (3,060 m)

FIGURE D4

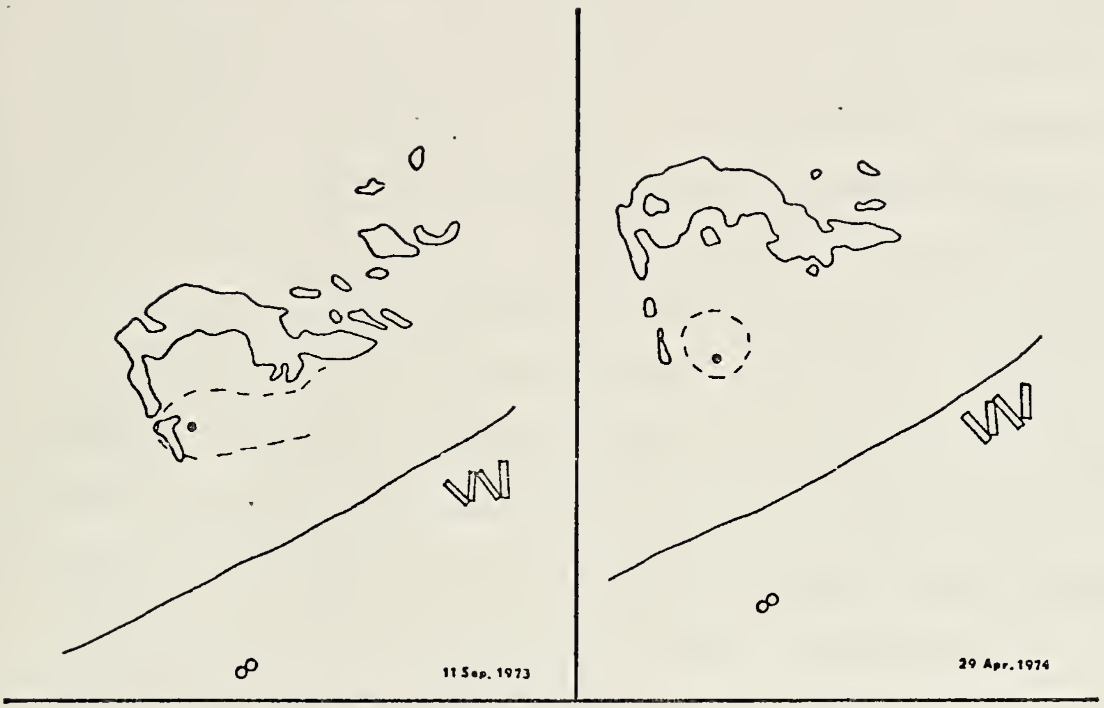
EFFLUENT PLUME PATTERNS

A subjective interpretation of distinctive water hue patterns in the vicinity of the Monterey sewer outfall was attempted in order to assess the possible extent of significant effluent effects on the surrounding canopy. The results show considerable variation in apparent effluent patterns possible (Figs. D5-D6). Further study, correlating effluent pattern to surface wind, dominant wave direction, mean current flow, diffusion theory, surf zone mixing, canopy extent, etc., would presumably allow a more comprehensive realization of the degree to which such plumes might interact with a kelp surface canopy (Dawson, 1959; North and Schaeffer, 1964). The original photographs from which the sketches following are based, were made available from the U. S. Army Corps of Engineers library, San Francisco, except for the 29 April 1974 photo which was obtained from Mr. Dan Miller of the California Department of Fish and Game.



Effluent Plume Pattern Interpretations of the City of Monterey Sewer Outfall

FIGURE D5



Effluent Plume Pattern Interpretations of the City of Monterey Sewer Outfall

FIGURE D6

APPENDIX E: WAVE REFRACTION — AN EXPERIMENT

Prior to evaluating the refracted wave energy incident upon each of the four underwater surveyed quadrat sites (see DISCUSSION & Haderlie et. al/, 1974) a comprehensive theoretical wave refraction analysis was attempted between the grid bathymetry boundaries of Pt. Cypress and Ft. Ord (see Fig. 1). The refraction program used in the comprehensive analysis was written by Grizwold (1963). Wave periods between 8 and 20 seconds, from incoming directions between northwest (315°) and west (270°), were considered. A small portion of two such computer plotted outputs (retraced by hand) are illustrated in Figs. E1A and E1B. As Table E and these two figures indicate, a greater number of long period refracted wave orthogonals theoretically arrive in the vicinity of Hopkins Marine Station, than near the Ocean House Apartments (see Fig. 17 to identify locations); the reverse is true of short period wave orthogonals.

The above theoretical prediction was qualitatively confirmed by analysis of wave traces taken with a Dynamic Products Model DP-200 portable pressure sensor. The sensor was emplaced offshore from Hopkins and the Ocean House Apts. in 40 feet (12.2 m) of water, between the time period 2343Z and 0135Z on 2-3 August 1974. Other pertinent data is listed in Table E under Experimental Results. The portable wave pressure sensor traces were analyzed for apparent mean wave period (Pierson, Neumann and James, 1967), at both offshore stations and the resulting values viz., $\bar{T}$ (apparent) = 8.7S

off Ocean House Apts., $\overline{T}$ (apparent) = 13.5 off Hopkins Marine Station, were recognized as being qualitatively consistent with theoretical expectations.

To estimate the wave spectra coming into these two locations during the time interval when the experiment was conducted, the Fleet Numerical Weather Central North Pacific Deep Water Wave Spectra program was examined for the 0000Z time frame at two grid points near Monterey (see Figs. E1A & E1B). The distribution of estimated wave energy was seen to be concentrated primarily between west and northwest directions. The period band widths with most energy were observed to be bimodal, with one peak occurring for periods of 6.3 seconds or less, the other peak being between 13.4 and 14.4 seconds. No wave spectra estimation was made of near shore generated (sea breeze) waves or swell coming from the southern hemisphere.

Since the pressure sensor recorded wave traces that were not corrected for depth attenuation, slightly longer apparent mean periods were computed than actually occurred. Also, <u>if</u> long periods with more energy were present near Hopkins Marine Station these periods would have been less attenuated with depth than short period waves, accentuating the difference in mean apparent period values obtained.

This experiment was extremely limited in scope. Considerably more extensive data collection will be needed to better judge the validity and applicability of this and other numerical refraction programs to ecological study.

TABLE E

A Wave Refraction Experiment

Theoretical Results:

Direction	Period (in seconds)	Vic. Hopkins* Marine Station	Vic. Ocean House Apartments
315°	10	2**	4
304°	10	1	2
	14	2	2
	18	4	1
292°	10	1	1
	14	1	2
	18	3	1

*See Fig. E1A to identify locations.

**No. wave orthogonals 3 cm down the beachline to either side of marked "X" in figures e.g., E1A, E1B, etc., as counted from wave refraction computer plots.

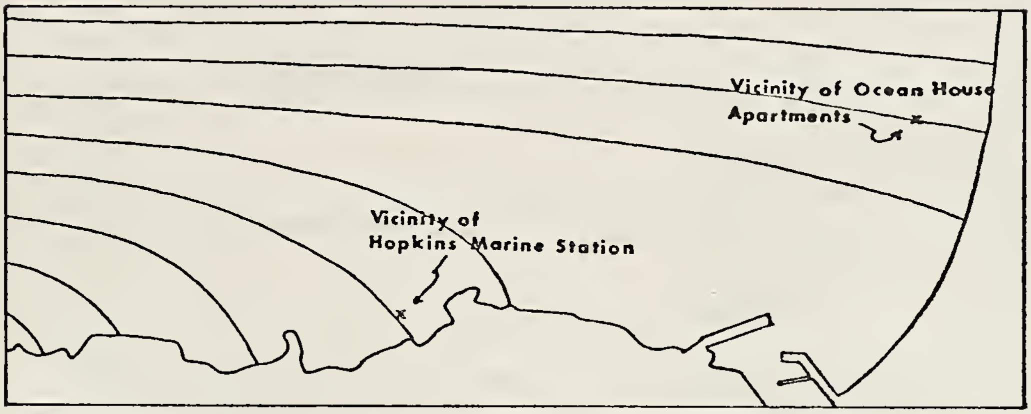
Experimental Results:

Date: 2-3 August 1974
Weax: Clear, except fog over mouth of bay
Wind: 10 kts, 245°T
Wave Record NR 1 (Hopkins Mar. Sta.): Time = 2343-0012Z, $\bar{T}$(apparent)† = 13.5S

Wave Record NR 2 (Ocean House Apts.): Time = 0053-0135Z, $\bar{T}$(apparent) = 8.7S

†$\bar{T}$ (apparent) is the mean value, of the periods observed from the wave sensor trace.

Portions of Computer Plotted Wave Refraction Diagrams



10 second period

FIGURE E1A

315° Deep water incoming wave direction

18 second period

FIGURE E1B

304° Deep water incoming wave direction

Computer Analyzed Deep Water Spectra for Two Grid Points
at 0000Z, 3 August 1974

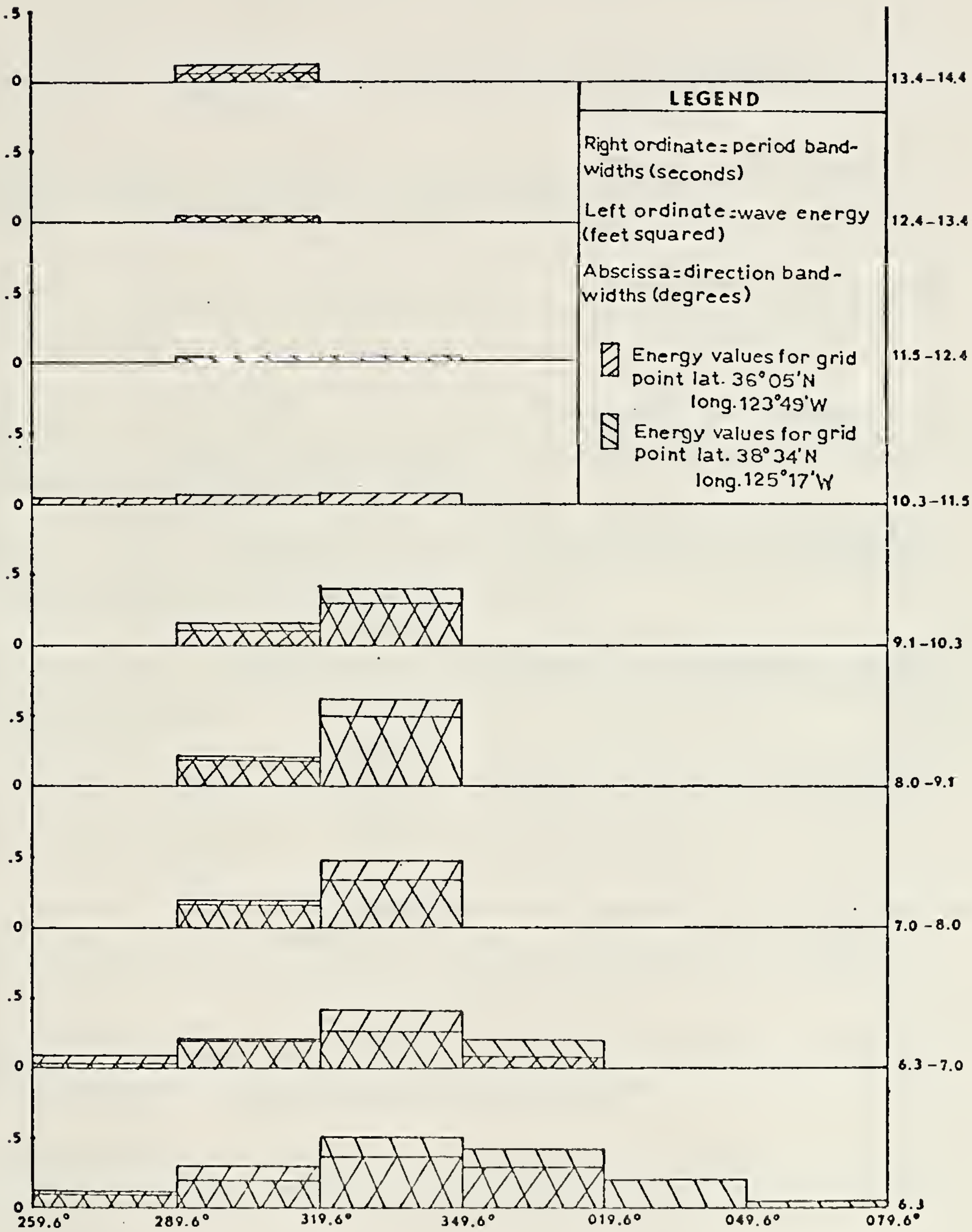


FIGURE E2

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